

2.4 Geology of the East Rand Basin

The local geological setting was derived from the Council for Geoscience (CGS) 2628AB, 2628AD, 2628BA, and 2628BC 1:50 000 Geological Map Series sheets. The geology map within the model domain can be seen displayed in Figure 2-4. The geological cross section was adapted from Lubbe et al., (2007) and is displayed in Figure 2-5. It should be noted that the purpose of this investigation was not to map in detail the sub-surface geology but rather correlate the structural geology of the basin with deep and shallow groundwater flow paths. The structural geology helped construct a numerical groundwater flow model.

The complex geological setting as adapted from Lubbe et al., (2007) can be best summarised in Table 2-2.

Table 2-2: Lithological Succession for the CGS 1:50 000 Map Sheet 2628AB adapted from Lubbe et al., (2007)

Supergroup	Group	Subgroup	Formation	
Quaternary deposits				
Karoo	Ecca		Vryheid (Pv)	
	Dwyka (C-pd)			
Transvaal	Pretoria		Hekpoort (Vh)	
			Boshoek (Vbo)	
			Timeball Hill (Vti)	
			Rooihoogte (Vrh)	
	Angular Unconformity			
	Chuniespoort	Malmani		Eccles (Ve)
				Lyttleton (Vly)
				Mote Christo (Vmo)
				Oaktree (Voa)
				Black Reef (Vbr)
Angular Unconformity				
Ventersdorp	Platberg (Rpl)		Undifferentiated	
Witwatersrand	Central Rand	Turfontein	Mondeor (Rmo)	
			Elsburg (re)	
			Kimberley (Rki)	
		Johannesburg (Rjo)	Undifferentiated	
	Angular unconformity			
	West Rand	Jeppesfontein (Rj)		Elandslaagte (Rel)
				Palmietfontein (Rpf)
		Government (Rg)		Tusschenin (Rts)
				Coronation (Rco)
				Promise (Rpr)
Hospital Hill (Rh)		Undifferentiated		
			Orange Grove (ror)	
Angular Unconformity				
Bryanston Gneiss (Zbr) and Zesfontein Gneiss (Ze)				

Mining in Witwatersrand Supergroup quartzites, shale and conglomerates followed the deformed sedimentary rocks of the ERB, more specifically, the Main Reef (situated in the Johannesburg Subgroup) and the Kimberley Reef that forms part of the Turfontein Subgroup. Witwatersrand sediments were deposited onto the granitic basement and were deformed by syndepositional forces which refer to stresses imposed onto the sediments while they are deposited and before they have lithified into rock.

The undifferentiated Johannesburg Subgroup consists mainly of quartzite and conglomerate. The Nigel Reef is the pebble marker containing chert, quartzite and porphyry and forms the of the basal part of the Mian Reef (Johannesburg Group). From the conceptual cross-section (Figure 2-5) the thickness of the Johannesburg Group underlying the Grootvlei #3 and #4 shafts is inferred to be approximately 200 m.

Should you drill deeper past the Johannesburg Subgroup, the Jeppestown Subgroup would be intersected for ~80 m until the basement Halfway House Granites are intersected. However, the thickness of the Jeppestown Subgroup can vary to be as thick as 520 m. Various (<40 m²) outcrops of the basal granites are observed within the ERB footprint and consisted of varying textures of light brown to cream reddish leucocratic fine- to medium-grained granite (Opperman et al., 2005). The authors observed that the granites do not intrude into the Witwatersrand Supergroup. The Krugersdorp Formation was deposited onto the Intrusive norite/granophyre and consists of an approximately 130 m thick sheet of coarse-grained quartzite. The bird member would account for approximately 40 m of that thickness.

Extensive lava flows of the Ventersdorp Supergroup overlaid the Witwatersrand Supergroup. However, due to the reef being poorly developed and of little to no economic value, the Supergroup was not extensively mapped within the model domain. A long period of erosion occurred following the deposition of the much younger Karoo sediments onto the Black Reef Formation Quartzites.

The Vredefort impact structure and the forming of the Johannesburg Dome influenced the deposition of pre-Palaeozoic sediments of the Karoo Supergroup. Horizontally underlain by the Dwyka Group and Vryheid Formation. Characteristic of the surface landscape within the East Rand Basin is the high-lying areas associated with sub-outcropping volcanosedimentary sequence of the Ventersdorp Supergroup, and the dolomites of the Malmani Subgroup underlay the flat topographies and wetlands of the basin.

Dykes and sills of various ages ranging from Archaean to Jurassic intruded into the Transvaal Supergroup and Witwatersrand Supergroup sedimentary rocks. The intrusive rocks come in the form of Syenite, Diabase and Ilmenite dykes that fed into sills crosscutting the Malmani Dolomites. The Modder East Dyke was digitized from the CGS 1:50 000 geological map series aeromagnetic survey (2628AB, 2628AD, 2628BA, 2628BC) and strikes south-east to north-west and was emplaced almost vertically. The CGS map sheets had a gap in the survey data (refer to Figure 2-6) and it was not clear if this dyke extends as a single structure to the north-west of the model boundary. The Modder Dyke is situated to the west and is parallel to the Modder East dyke. The pre-Transvaal faulting observed on the geological map (Figure 2-4) was georeferenced from in the cross-section adapted from (Lubbe et al., 2007).

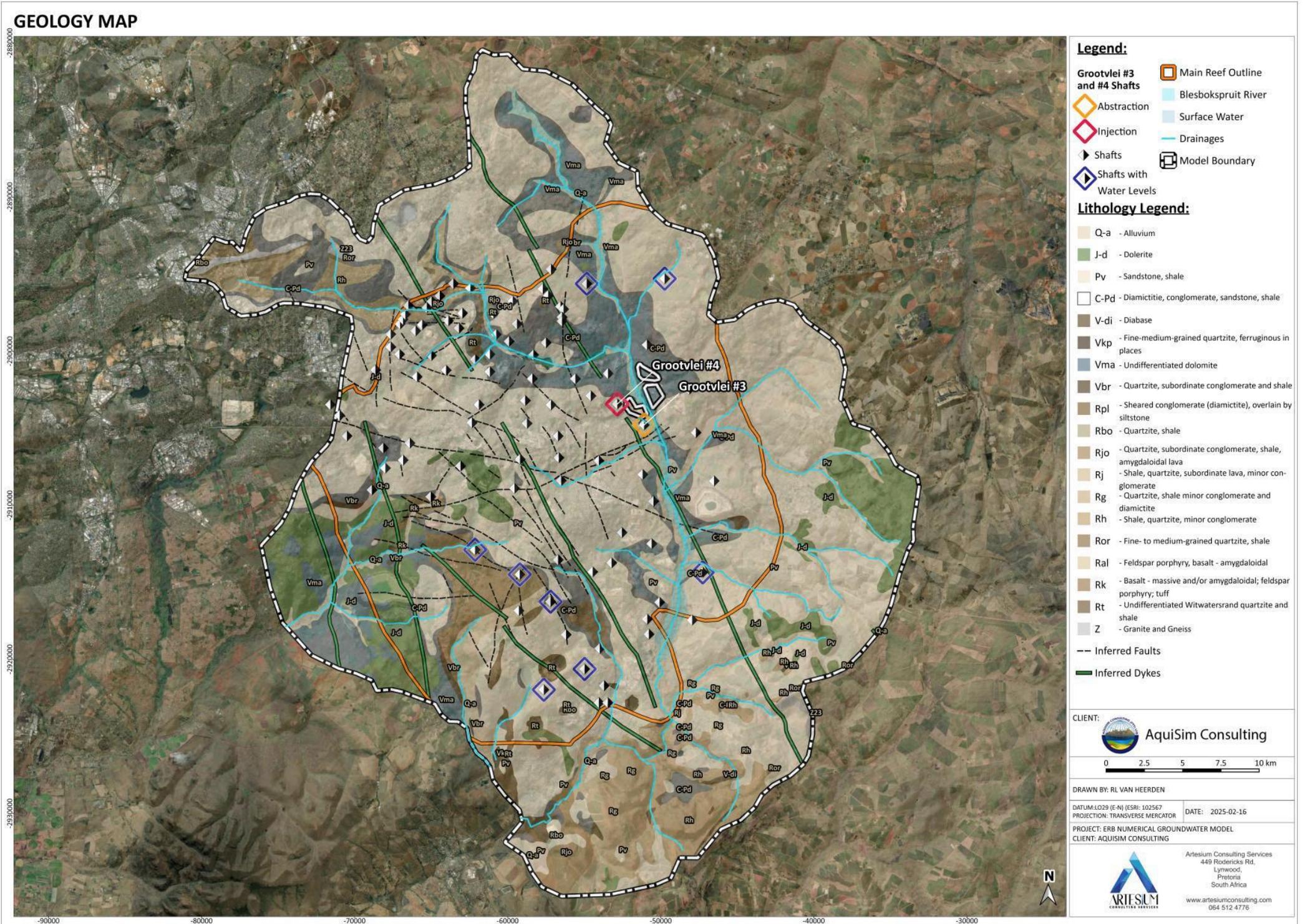


Figure 2-4: Geology Map adapted from 1:50 000 CGS Geological Map Series

GEOLOGICAL CROSS SECTION ADAPTED FROM 1:50 000 CGS GEOLOGICAL MAP EXPLANATION (2628AB BENONI)

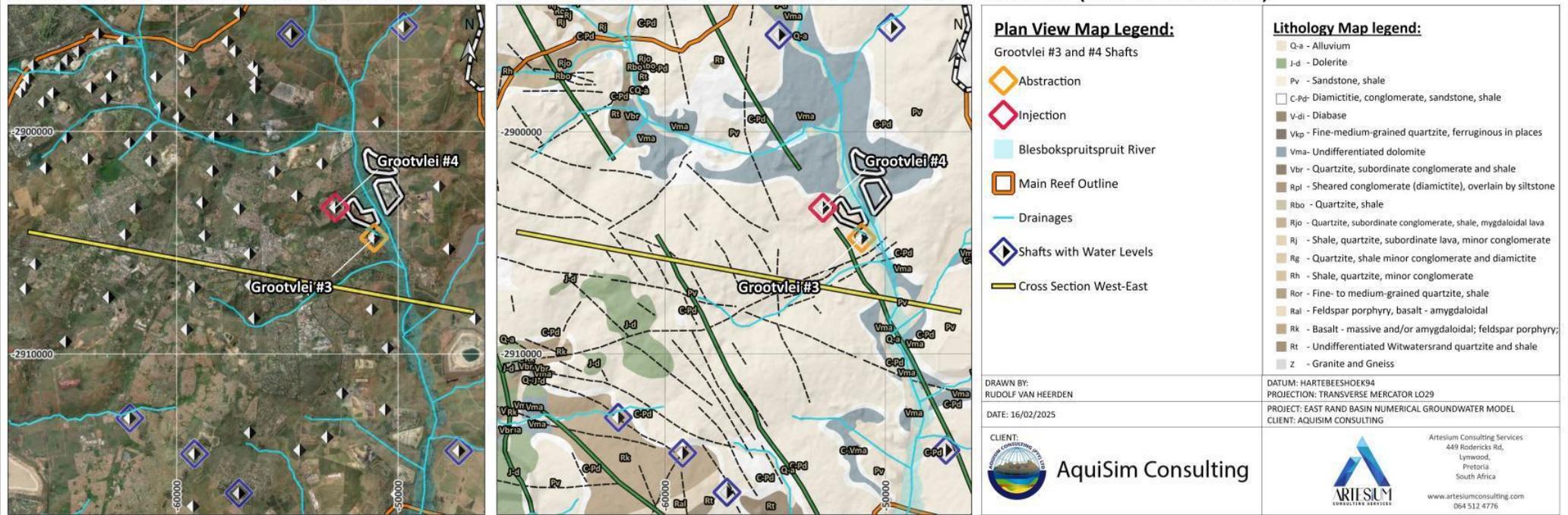


Figure 2-5: Geological Cross-section adapted from Lubbe et al. (2007)

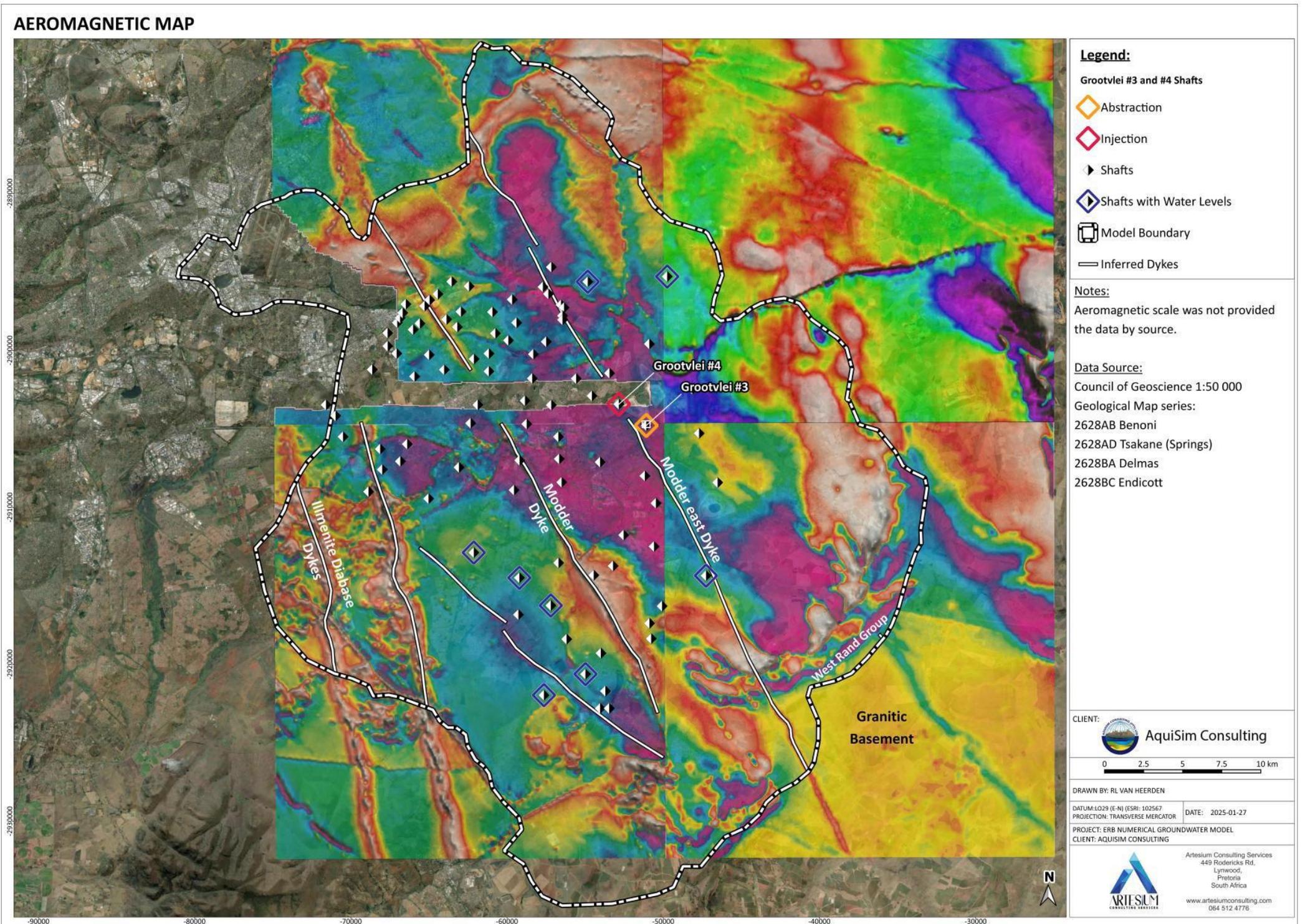


Figure 2-6: Aerial Magnetic Map Adapted from CGS 1:50 000 Geological Map Series

2.5 Hydrogeology of the East Rand Basin

The ERB falls within the Vaal Water Management Area (WMA) bordering the Limpopo WMA to the north-west and the Olifants WMA to the north-east (DWS, 2016). The model domain stretches across the quaternary catchments C21D, C21E, C21F, and C22C with the details for the respected catchments summarised in Table 2-3.

Table 2-3 Quaternary Catchment A21C and C22A Information

Quaternary Catchment	Total Area (km ²)	Recharge (mm/a)	Current use (l/s)	Rainfall (mm/a)	Groundwater levels (mbgl)
C21D	445.8	5.7	26.7	698	16.7
C21E	628.2	5.1	7.0	690.7	14.9
C21F	426.6	6.2	18.7	703.7	11.2
C22C	465.2	6.3	0.9	683.8	11.3

The 1:500 000 Hydrogeological Map Series sheet 2526 Johannesburg (Barnard & Baran, 1999) is displayed in Figure 2-8. The Blesbokspruit and beneath the ERB plant is underlain by Karst type (c5) aquifer with typical borehole yields of > 5 l/s. The main aquifer within the model domain is the Chuniespoort Group (dolomites) that were deposited in westward dipping synform known as the Potchefstroom Synclinorium (Foster, 1988). The majority of the model domain is situated on top of an Intergranular and fractured type aquifer (d2) with typical borehole yields between 0.1 and 0.5 l/s. The author Barnard and Baran (1999) identified the major zones for groundwater as the following:

- Basins of weathering occurring mostly in igneous rocks.
- Joints and fractures in competent arenaceous rocks related to tensional or compressional stresses and off-loading.
- Solution channels and fractures in the carbonate rocks (differentiated dolomite) of the Chuniespoort Group in the dolomite aquifer that underlies the Karoo Sediments to the east of the site (refer to Figure 2 7).
- Joints and fractures occurring in contact zones related to the heating and cooling of country rock, caused by the intrusion of dykes and sills. Modder east and Modder dyke that strikes south-east to north-west.
- Fractures in transitional zones between weathered and unweathered rocks.
- Along contact zones between sedimentary or volcanosedimentary sequences (Ventersdorp Supergroup). Contacts may be:
 - Open;
 - Weathered or fractured along unconformities;

- Fractured along dynamic contacts zones;
- Fractured due to heating and cooling along large extrusive events (Ventersdorp lava flows).
- Faults and associated shear zones as is evident in the major structures within the basin such as the northwest-southeast oriented fold axis, the Springs monocline (refer to cross-section Figure 2-5) that strikes from northwest to southeast, a number of left-lateral faults and anastomosing faults, and thrust faults that are mainly oriented north-south.

Groundwater recharge to the Main Reef and Kimberley Reef are expected to occur via the following main pathways.

- Recharge from surface rainfall via dissolution channels (sinkholes and dolines) in the dolomite (refer to Figure 2-7).
- Recharge from surface water (rainfall) ingress through underground workings.
- The shaft annulus would act as a conduit for surface water to recharge the deeper groundwater.
- Deep basin flow across regional catchments.
- Direct recharge or constant recharge boundary via the Blesbokspruit River.



Figure 2-7: Visible Sinkholes from Sattelite Imagery (Esri, 2025)

From previous hydrochemistry and isotope studies conducted by (Exigo, 2017) it was concluded that the main recharge mechanism is surface water recharging the basin via dissolution channels in the dolomite and the underground workings. The footprints of the underground workings are now known at the time of this study. The sinkholes (especially to the east of the site) could be mapped via satellite imagery (Figure 2-7). The sinkholes could have formed as a result of collapsed shallow mine workings or from weathered dolomite and resulting sinkholes and/or dolines that formed. It was assumed that the main reef outcrop due to the reef being extensively mined out, would also act as a preferential pathway for surface water to recharge the basin.

The basin and lower-dolomite aquifer is semi-confined by an aquitard (Karoo Dolerite Suite) that was emplaced into the surrounding strata, along with ilmenite and diabase sills. The aquitard therefore separates the main dolomite aquifer into an upper (unconfined) and lower (semi-confined) aquifer system. It was assumed that the ERB was regionally semi-confined and locally connected to surface via recharge received from the Blesbokspruit and associated recharge pathways via dolomite dissolution channels. The shafts penetrate through the confining layer into the lower semi-confined aquifer. The degree of weathering of the shaft infrastructure is not known and it is assumed that they reach up to the Main Reef and Kimberley Reef.

2.5.1 Radiological Count of the East Rand Basin

From a desktop background the existing radiological count status map of the model domain can be seen displayed in Figure 2-9. The map data was georeferenced from the CGS 2628AB, 2628AD, 2628BA, and 2628BC 1:50 000 Geological Map Series sheets. The survey recorded four radiometric channels namely; total count, potassium (red), thorium (blue), and uranium (green). The following conclusions were made with regards to the radiological count in the model domain:

- Higher concentrations were observed along mining activity such as Tailings Storage Facilities (TSF's) and open diggings (open cast mine workings). To the north-west of the Grootvlei #3 and #4 shafts, higher intensity signatures were detected correlating with other shaft locations. The shaft localities throughout the model domain correlated with increased radiometric counts.
- A higher signature of Thorium was identified in the middle TSF situated 3 km to the north of the Merryvale #5 shaft and to the south of the N17 in the vicinity of Daggafontein. Another such signature was identified on a rehabilitated TSF situated to the west of the Merryvale #5 shaft.
- Ebotse Golf and Country Estate had a high signature. The Benoni Country Club is situated directly to the east and borders the aforementioned golf estate and had the inverse signature, possibly attributed to the two golf courses irrigating from two separate surface/groundwater sources, with the inverse radiometric counts. The source of the irrigation for these golf courses are not known.
- Surface water features had high radiometric counts. The evaporative pans would concentrate radiological material as they have a higher evaporation rate compared to recharge rate. Certain surface water features like the Pomula Park Nature Reserve dam and the Vanryn Dam had low

radiometric signature compared to the other surface water bodies.

- Elevated levels of Uranium (red) is evident along the footprint of the Blesbokspruit River.
- Intermediate concentrations of radiometric concentrations were identified along fluvial pathways in the south-east part of the model domain.
- Various linear anomalies are situated to the north-east of the model boundary and are associated with the Klapperkop Quartzite Member of the Pretoria Group.

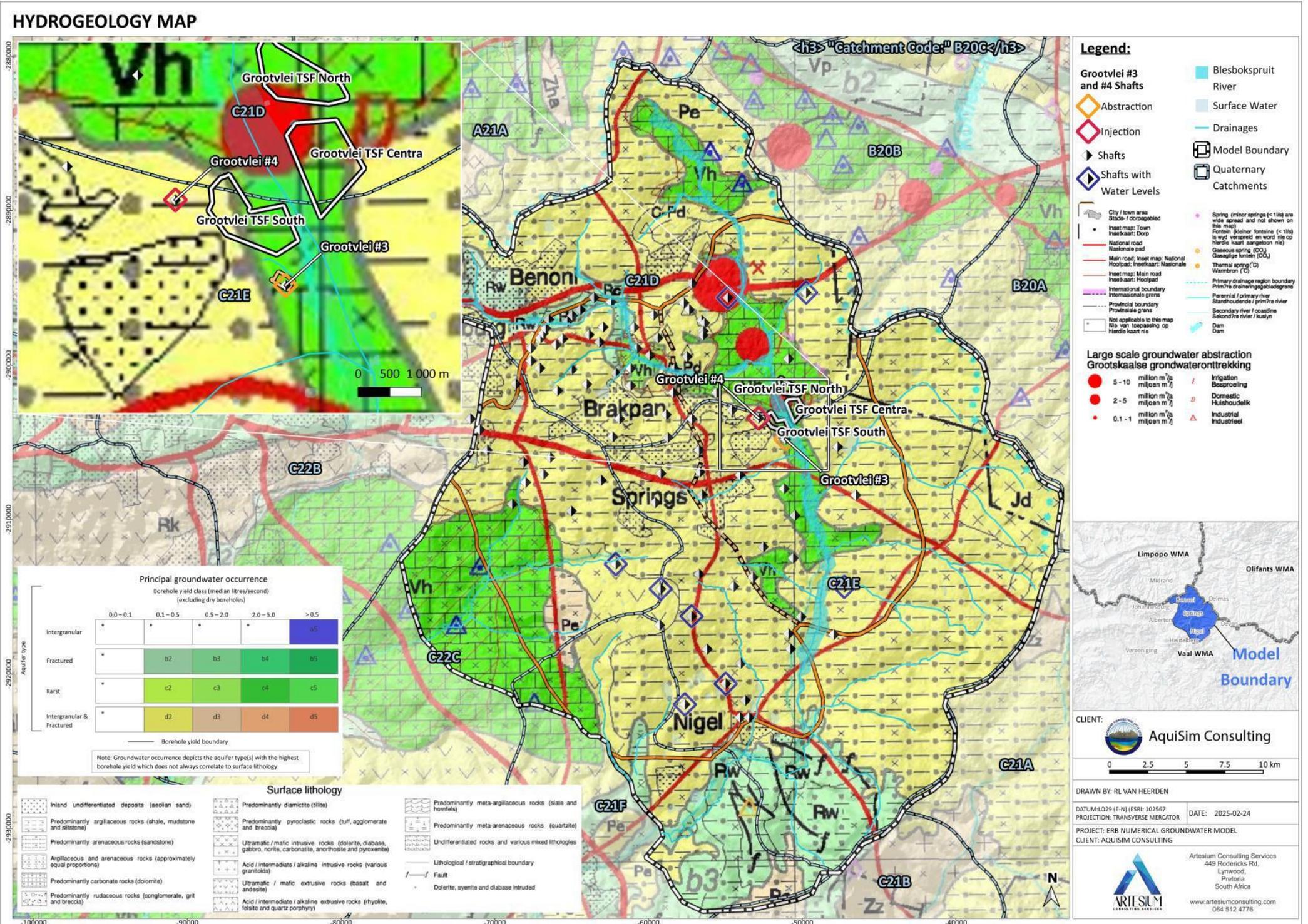


Figure 2-8: Hydrogeology Map

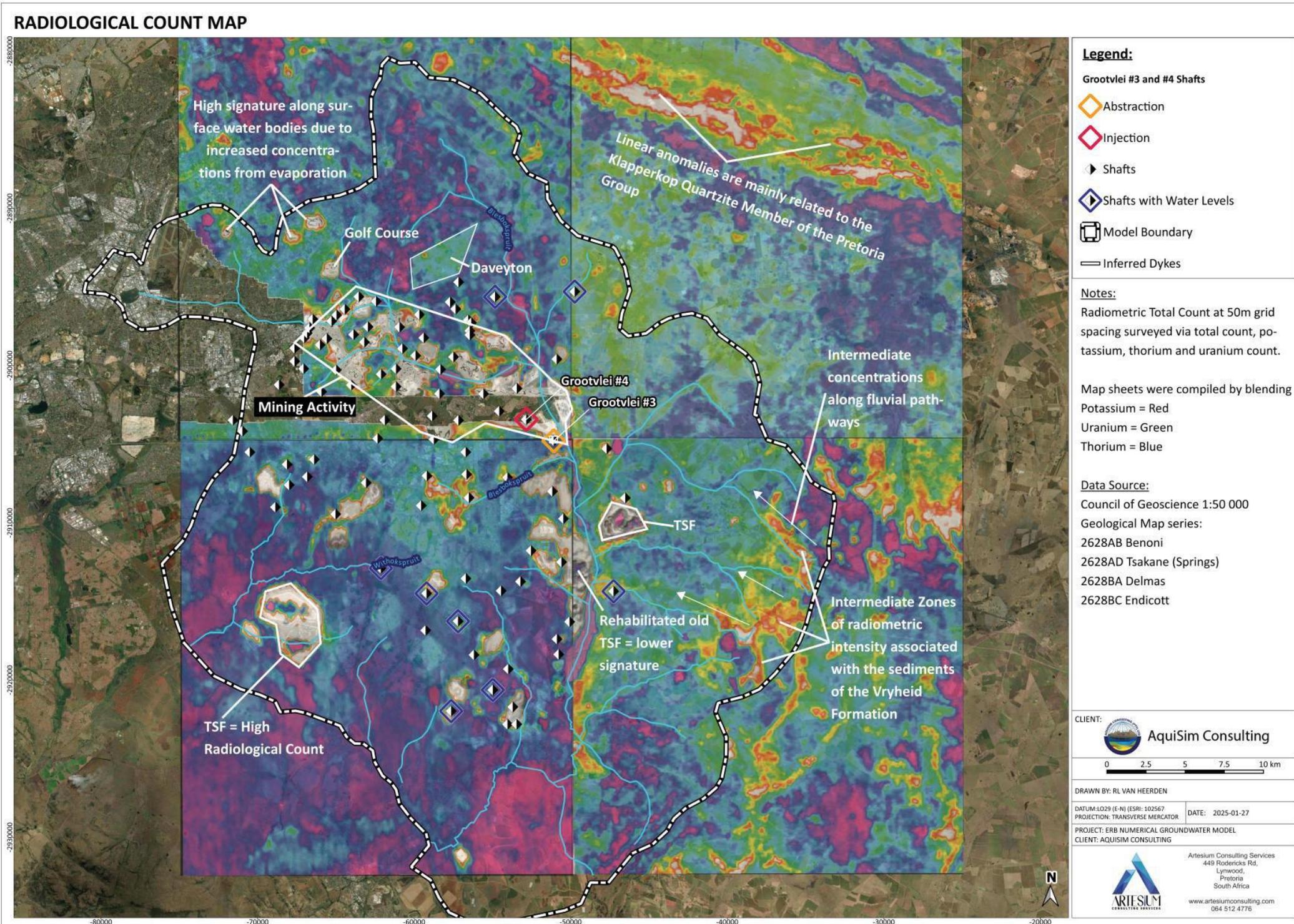


Figure 2-9: Radiological Count Map

3 METHODOLOGY

3.1 Historical Report Review

The following existing data sources were available for the study area and was used to provide background for the numerical groundwater model update:

- Conceptual groundwater flow model of the Far East Rand Basin – Grootvlei sub-catchment Phase I. (AGES Technical Report no.:AG/R/04/11/29, dated November 2004).
- Groundwater flow model of the Far East Rand Basin – Grootvlei sub-catchment Phase II: Calibrated for the Canal Area. (AGES Technical Report.: AS/R/05/04/01, dated April 2005).
- Regional groundwater flow management model for the Far East Rand Basin. (AGES Technical Report no.: AS/R/06/02/10, dated February 2006).
- East Rand Basin Flooding and Sludge Disposal: Flow and Mass Balance Modelling. (Exigo Groundwater specialist report Draft no.: ES15/205 V2, dated 10August 2017).
- Nafasi ERB AMD Water Level Rise Investigation – Risk Assessment. (Artesium SA Technical Report no.: 2022-067, dated 8 November 2022).

3.2 Project Background

- **2003:** A groundwater flow model was developed and calibrated focusing on the surface water groundwater interaction at the Florida Lake sub-catchment in the Central Rand Basin.
- **2004:** A conceptual groundwater flow model in the Grootvlei Mine sub-catchment was developed to qualify the origin of the water that is dewatered at Grootvlei #3 shaft at a rate of 75 000 m³/d. It was identified that 70 % of the water originates from surface water inflow from the Blesbokspruit, Alexander and Cowles Dam. The water balance and saturated state (i.e. shallow water levels) of the Karoo and Dolomite Aquifers indicated that the groundwater inflow component was in the order of 30 % (23 000 m³/d). There was however no detailed piezometric head elevation data to confirm the conceptual groundwater flow model indications. Recommendations were made to confirm the model with the development of monitoring boreholes during the follow up phase.
- **2005:** Seven monitoring boreholes were drilled in the proposed canal area in the Blesbokspruit at Grootvlei Mine's West Pit and Shaft No 9. The monitoring borehole data confirmed that the piezometric head gradients are from the spruit to the groundwater system. The calibrated model indicated that up to 10 000 m³/d, which represents 12 % of the inflow could seep from the canal area. Recommendations were made to extend the surface water drainage or isolation option to Alexander and Cowles Dam.
- **2006:** From the previous Groundwater flow model the most important ingress zones identified was the Cowles Dam 15 000 m³/d (42 %) and the West Pit canal area 10 000 m³/d (28 %), that contributes 70 % of

the ingress volume of 35 000 m³/d. The Blesbokspruit sub-catchment is the most important and accounts for 70 000 m³/d (80 %) of the abstracted volume. The original base flow of the Blesbokspruit is reduced by 42 % from 80 000 m³/d to 46 000 m³/d. The Sallies and Brakpan Basins account for 15 000 m³/d (20%) of the abstracted volume, which originates from both the Blesbok Spruit and the Withok Spruit catchments. The Withokspruit accounts for only 3 000 m³/d (3.5 %) of inflow into the underground mine workings.

- **2017:** A water flow and mass balance model was developed by Exigo (2017) to ERB to determine the dynamics and potential for sludge disposal and the associated potential impacts on the water environment. It was proved with hydrochemistry isotope analysis that 65% of the water pumped from Grootvlei #3 shaft originates from the Blesbokspruit and only 35% comes from the dolomite aquifer. The Erwat Plants to the north and up-gradient of the ERB plant also discharges 140 ML/d of water into the Blesbokspruit. The influence of the sludge disposal is positive as the calcium carbonate in contact with the AMD (Acid Mine Drainage) water has a very long residence time to further buffer pH and the physical filling of the mine void reduces the oxygen levels which would reduce pyrite and uranium leaching.
- **2022:** ACS analysed the rise of water levels in the ERB since from the Grootvlei #3 shaft during February 2022. The analysis was conducted to investigate risk of possible surface and sub-surface decanting, estimate potential timescale to decant, and recommend monitoring and management options. A negative correlation between rate of basin water rise and the basin water level itself was observed. It is proposed that this may be due to the shape of the basin, the concentration of shallow mine voids and subsurface decant into the dolomite aquifers. Decant areas of lowest topographic elevation near canal from Nigel Dam enters Nigel Town (bridge at R42) was identified. By the time decant at surface would occur, significant sub-surface decant will already have taken place. This poses a risk to groundwater aquifer water quality and also to building foundations.

3.3 Grootvlei Shaft Abstraction and Injection Monitoring Data

The Grootvlei #3 shafts main function is to abstract water from the Grootvlei sub-basin in order to keep the Acid Mine Drainage (AMD) from decanting at surface. The abstraction aims to keep the water level in the shaft below the Environmental Critical Level (ECL) situated at 1 470 mamsl. The Nigel #1 shaft was identified as the shaft were decant is most likely to occur, with the shaft top situated at 1 550 mamsl. Dewatering started 01 March 2015 until present, and was provided in daily flow meter readings (daily volumes). The statistical summary of the mentioned data is provided in Table 3-1 with the localities of the shafts displayed in Figure 2-2. The average pumping rate at Grootvlei #3 shaft is 70 250 m³/d. The water is abstracted at approximately 160 mbgl, equating to approximately 1 405 mamsl.

Table 3-1: Grootvlei Shaft Abstraction and Injection Volumes Statistical Analysis

ID	Abstraction Volumes (m ³ /d)	Deposition Volumes (m ³ /d)
Max	104 977	4 053
P99	104 870	3 808
P95	102 741	3 097
P50	70 250	1 614
Average	70 250	1 614
P05	32 751	618
Min	12 686	0

The integrity of the shaft walls is not known, and neither the shaft dimensions (diameter). A study conducted by MacConachie (1959) on typical shaft construction in the East Rand Basin suggested that most of the shafts were constructed with a diameter of 5.4864 m and these dimensions were used for all calculations in the simulations. The degree of weathering of the shaft and possible placement of plugs and access tunnels would effect the flow dynamics between shafts and as a results effect the basin flow pathways. The walls of the shafts were assumed to be relatively weathered in this study, and thus water can be abstracted and injected at various levels (elevations). It was assumed that the total depth of the Grootvlei #3 shaft is equal to the depth of Main Reef at the shaft location (1 172 m).

Grootvlei #4 shaft injects on average 1 614 m³/d of sludge into the shaft at 700 mbgl via unknown mechanism. It was assumed that the sludge is pumped into the shaft and settles via gravity to the bottom of the Grootvlei sub-basin (Figure 3-5). The depth of disposal would indicate that the injection takes place in Kimberley Reef. However, if it is assumed that that the sludge would settle to the lowest point through gravity feed, it would settle in the lowest part of the Grootvlei sub-basin and therefore in the main reef. The exact depth of the shaft is also not known, and it was assumed that the shaft would have been sunk to access both the Main Reef and the Kimberley Reef during active mining. The total assumed depth of Grootvlei #4 shaft is therefore 1 223 m.

3.4 East Rand Basin Hydraulic Heads

The ERB Plant hydraulic heads (surface elevation minus the measured water level) trends are plotted below in Figure 3-1. The Grootvlei #3 shaft displays a deeper calculated hydraulic head compared to the shallow boreholes (EBH-01 – EBH04). EBH-01 – EBH-04 are drilled 20.46, 19.95, 20.17, and 30.38 m deep, respectively. The shaft had an assumed depth of 1 172 m. The shaft has a deeper on average measured hydraulic head compared to the shallow monitoring boreholes despite being within close proximity to each other (EBH-04 is situated 80 m to the east). The lack of drawdown observed in the shallow boreholes proves that the Blesbokspruit is constantly recharging the shallow aquifer.

The Grootvlei #3 shaft water level increased to above the ECL (May 2021) following an increase in rainfall (CRD trend) coupled with a decrease in pumping at the same time. The water level increased to within approximately 15 m of decanting at the Nigel #1 shaft located (16 km) to the south and down-gradient of the ERB Plant. An increase in pumping rates has since decreased the hydraulic head in the basin to within 10 m

above the ECL as of December 2024.

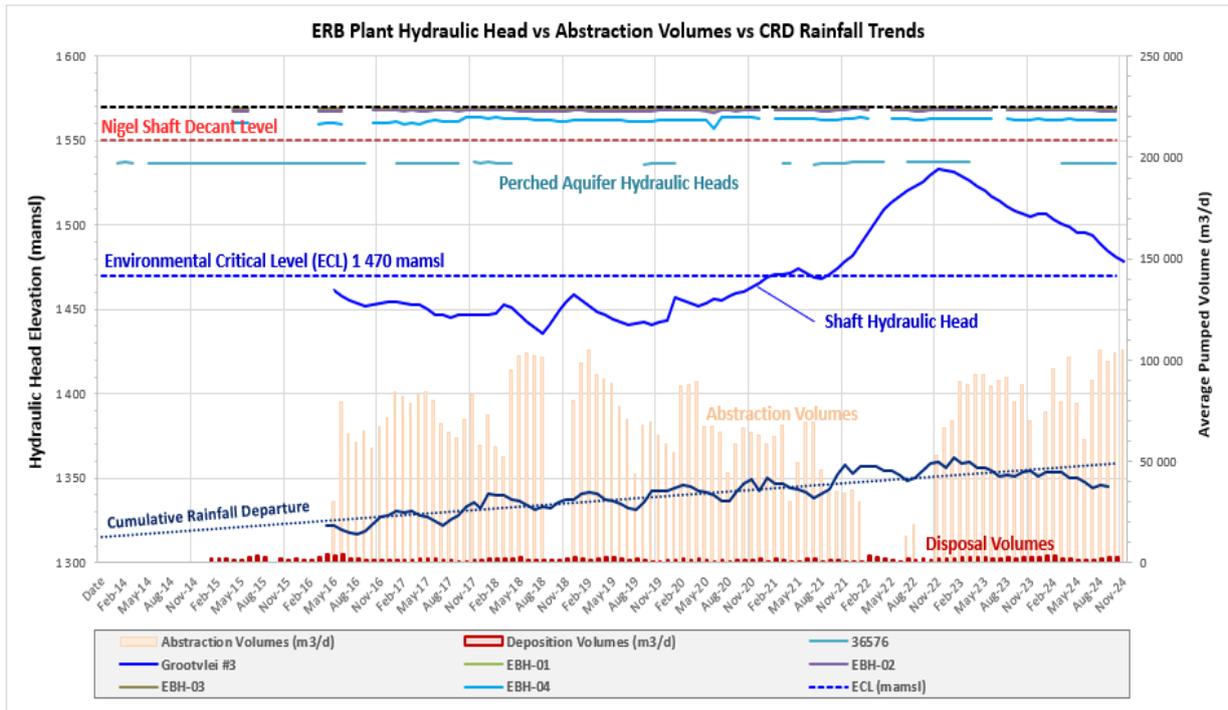


Figure 3-1: ERB Plant Hydraulic Head and Abstraction/Inhection Volumes vs Cumulative Rainfall Trend

The summary of historical monitoring record for the East Rand Basin (within the delineated model boundary) is shown in Table 3-2. The data was gathered from ACS monitoring database, ACS report archives, and additional data was provided by the DWS. The monitoring record was for both shaft and borehole water levels.

Overall, from the total 103 data points, 84 had single data points (i.e. one measured water level on record). Nineteen (19) sites had records stretching on average 2 years, with one borehole (ID: 36576) having a 38 year record and the boreholes at the plant being monitored for the past 10 years. Of the 19 sites with monitoring records, 6 had a decreasing trend of 6 m on average and 13 had an increase in water level of 225 m on average. The higher rise in water level is attributed to the shaft water levels increasing on average 323 m compared to the boreholes that had an average increase of 4 m.

The available long-term monitoring data trends of recorded hydraulic heads for the ERB watershed (Figure 3-1 to Figure 3-3), with the spatial distribution of the sites shown in Figure 2-3 and Figure 3-1. The following was concluded:

- Shaft water levels have increased correlating with the Cumulative Rainfall Departure (CRD) trend.
- The Vlakfontein Deep #2, Vlakfontein#1, and Holfontein #1 shafts show an increasing trend in water levels, however, do not show the seasonal variation in water levels. These shafts also have shallower water levels on average compared to the other deeper shafts

- Borehole water levels are stable over time in boreholes GP00501, GP00502, GP00499, EBH-01, EBH-02, EBH-03, EBH-04.
- The deepest water level (1 514 mamsl) was measured in GP00500 in September 2024, with the borehole displaying a downward trend.
- The boreholes situated in the shallow and perched aquifer system do not display the same seasonal trends as the shafts situated beneath the aquitard

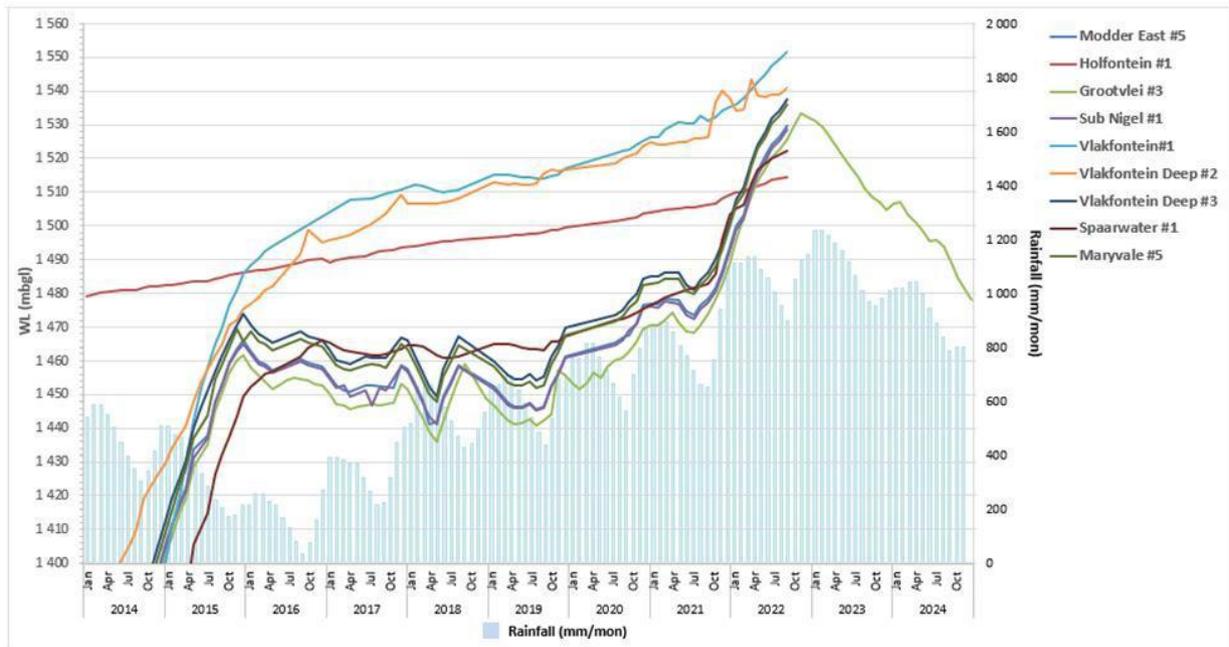


Figure 3-2: Recorded Hydraulic Head Measurements for Shafts Located in the ERB vs CRD Trends

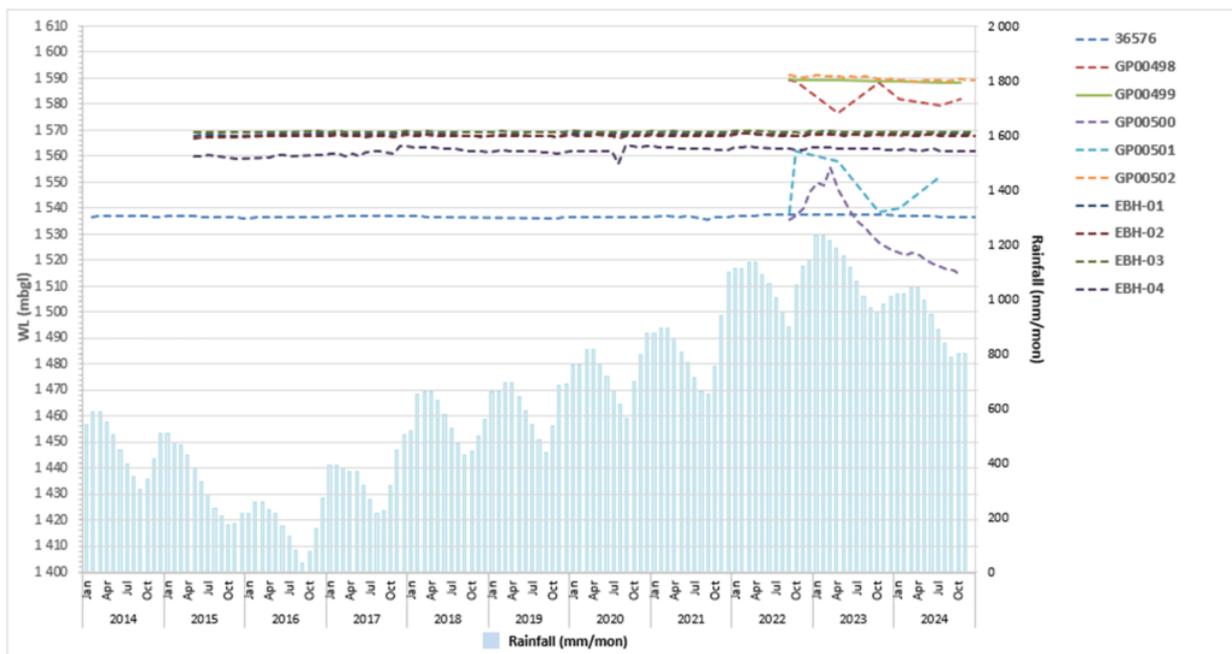


Figure 3-3: Recorded Hydraulic Head Measurements for Boreholes Located in the ERB vs CRD Trend

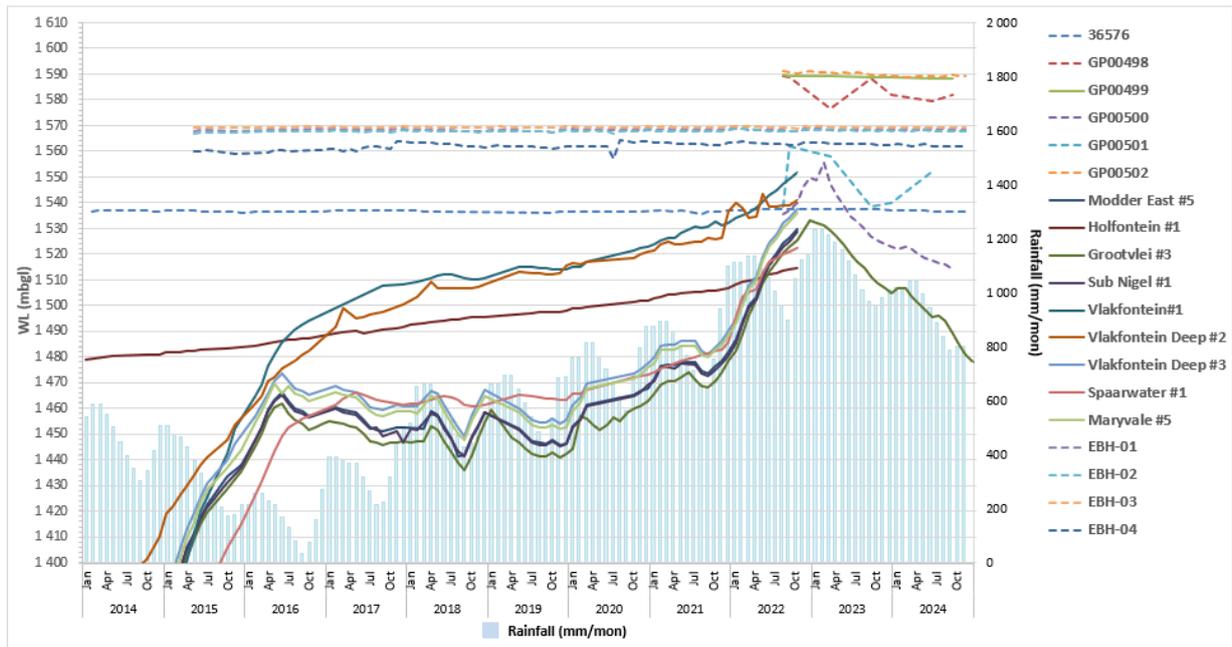


Figure 3-4: Recorded Hydraulic Head Measurements displayed Together to show |Correlation between Deep and Shallow Hydraulic Heads vs CRD Trend

Table 3-2: Water Level Monitoring Database for Boreholes and Shafts within the Model Boundary

Site ID	Site ID	X LO_29	Y LO_29	Z (mamsl)	Average of Hydraulic Head (mamsl)	P95 of Hydraulic Heads (mamsl)	P50 of Hydraulic Heads (mamsl)	Number of Data Points (count)	First Measured Hydraulic Head (mamsl)	Last Measured Hydraulic Head (mamsl)	Difference (m)	Trend First to Last	First Measured Date	Last Measured Date	Record Span (years)
Statistical Analysis for All Data Points															
				Max	1 633	1 633	1 633	3 039	1 633	1 633	483				38
				P95	1 624	1 624	1 624	109	1 624	1 624	288				10
				P50	1 582	1 582	1 582	1	1 582	1 582	0				0
				Average	1 571	1 579	1 572	50	1 551	1 579	28				2
				P05	1 465	1 517	1 465	1	1 232	1 517	0				0
1	36576	-74 013	-2 917 212	-2 917 212	1 537	1 538	1 537	293	1 538	1 537	-1	Decrease	1987/01/20	2024/11/21	38
2	GP00498	-43 650	-2 919 613	-2 919 613	1 584	1 589	1 582	7	1 589	1 582	-7	Decrease	2022/08/14	2024/09/18	2
3	GP00499	-43 638	-2 919 106	-2 919 106	1 589	1 590	1 589	7	1 590	1 588	-2	Decrease	2022/08/14	2024/09/18	2
4	GP00500	-48 000	-2 917 282	-2 917 282	1 532	1 549	1 532	29	1 536	1 514	-22	Decrease	2022/08/17	2024/09/18	2
5	GP00502	-43 295	-2 919 617	-2 919 617	1 590	1 591	1 590	28	1 591	1 589	-2	Decrease	2022/08/17	2024/11/13	2
6	EBH-03	-50 951	-2 904 699	-2 904 699	1 569	1 570	1 569	103	1 569	1 569	0	Decrease	2015/05/01	2024/11/28	10
7	GP00501	-48 098	-2 916 338	-2 916 338	1 548	1 561	1 546	6	1 538	1 552	14	Increase	2022/08/14	2024/06/20	2
8	Modder East #5	-54 828	-2 895 624	-2 895 624	1 449	1 521	1 460	105	1 046	1 530	483	Increase	2012/06/26	2022/10/19	10
9	Holfontein #1	-49 742	-2 895 293	-2 895 293	1 496	1 512	1 496	107	1 478	1 515	36	Increase	2012/06/26	2022/10/19	10
10	Grootvlei #3	-51 082	-2 904 784	-2 904 784	1 473	1 528	1 461	3 039	1 185	1 477	293	Increase	2013/09/10	2024/12/10	11
11	Sub Nigel #1	-54 974	-2 920 625	-2 920 625	1 263	1 499	1 196	337	1 046	1 528	483	Increase	2012/06/26	2022/10/19	10
12	Vlakfontein#1	-59 207	-2 914 489	-2 914 489	1 470	1 545	1 515	103	1 143	1 552	409	Increase	2012/08/16	2022/10/20	10
13	Vlakfontein Deep #2	-62 127	-2 912 884	-2 912 884	1 486	1 540	1 512	109	1 295	1 541	246	Increase	2012/08/16	2022/10/20	10
14	Vlakfontein Deep #3	-57 195	-2 916 256	-2 916 256	1 464	1 528	1 468	102	1 225	1 537	312	Increase	2013/11/13	2022/10/20	9
15	Spaarwater #1	-57 635	-2 921 969	-2 921 969	1 424	1 518	1 464	109	1 044	1 522	479	Increase	2012/08/07	2022/10/19	10
16	Maryvale #5	-47 259	-2 914 353	-2 914 353	1 423	1 506	1 408	263	1 369	1 536	167	Increase	2014/12/02	2022/10/19	8
17	EBH-01	-51 193	-2 904 558	-2 904 558	1 568	1 569	1 568	103	1 568	1 568	0	Increase	2015/05/01	2024/11/28	10
18	EBH-02	-51 085	-2 904 620	-2 904 620	1 568	1 568	1 568	103	1 567	1 568	1	Increase	2015/05/01	2024/11/28	10
19	EBH-04	-51 004	-2 904 800	-2 904 800	1 562	1 564	1 562	103	1 560	1 562	2	Increase	2015/05/01	2024/11/28	10
20	GP129	-65 956	-2 901 366	-2 901 366	1 576	1 576	1 576	1	1 576	1 576	0	Single Data Point	2005/08/05	2005/08/05	0
21	GP130	-62 928	-2 901 251	-2 901 251	1 616	1 616	1 616	1	1 616	1 616	0	Single Data Point	2005/08/05	2005/08/05	0
22	GP131	-63 001	-2 901 275	-2 901 275	1 616	1 616	1 616	1	1 616	1 616	0	Single Data Point	2005/08/05	2005/08/05	0
23	GP132	-68 147	-2 906 105	-2 906 105	1 564	1 564	1 564	1	1 564	1 564	0	Single Data Point	2005/08/05	2005/08/05	0
24	GP133	-62 224	-2 904 311	-2 904 311	1 623	1 623	1 623	1	1 623	1 623	0	Single Data Point	2005/08/04	2005/08/04	0
25	GP134	-63 289	-2 907 975	-2 907 975	1 612	1 612	1 612	1	1 612	1 612	0	Single Data Point	2005/08/04	2005/08/04	0
26	GP135	-64 846	-2 909 456	-2 909 456	1 565	1 565	1 565	1	1 565	1 565	0	Single Data Point	2005/08/03	2005/08/03	0
27	GP136	-66 174	-2 910 832	-2 910 832	1 577	1 577	1 577	1	1 577	1 577	0	Single Data Point	2005/08/02	2005/08/02	0
28	GP137	-68 715	-2 911 713	-2 911 713	1 560	1 560	1 560	1	1 560	1 560	0	Single Data Point	2005/08/03	2005/08/03	0
29	GP138	-44 767	-2 911 577	-2 911 577	1 576	1 576	1 576	1	1 576	1 576	0	Single Data Point	2005/07/26	2005/07/26	0
30	GP139	-45 608	-2 911 557	-2 911 557	1 571	1 571	1 571	1	1 571	1 571	0	Single Data Point	2005/07/27	2005/07/27	0
31	GP140	-45 618	-2 911 555	-2 911 555	1 572	1 572	1 572	1	1 572	1 572	0	Single Data Point	2005/07/27	2005/07/27	0
32	GP141	-47 508	-2 914 369	-2 914 369	1 567	1 567	1 567	1	1 567	1 567	0	Single Data Point	2005/07/28	2005/07/28	0
33	GP142	-48 477	-2 915 340	-2 915 340	1 568	1 568	1 568	1	1 568	1 568	0	Single Data Point	2005/07/28	2005/07/28	0
34	GP143	-51 683	-2 913 688	-2 913 688	1 571	1 571	1 571	1	1 571	1 571	0	Single Data Point	2005/07/29	2005/07/29	0
35	GP144	-50 291	-2 909 321	-2 909 321	1 554	1 554	1 554	1	1 554	1 554	0	Single Data Point	2005/07/30	2005/07/30	0

Site ID	Site ID	X LO_29	Y LO_29	Z (mamsl)	Average of Hydraulic Head (mamsl)	P95 of Hydraulic Heads (mamsl)	P50 of Hydraulic Heads (mamsl)	Number of Data Points (count)	First Measured Hydraulic Head (mamsl)	Last Measured Hydraulic Head (mamsl)	Difference (m)	Trend First to Last	First Measured Date	Last Measured Date	Record Span (years)
36	GP145	-51 486	-2 922 532	-2 922 532	1 553	1 553	1 553	1	1 553	1 553	0	Single Data Point	2005/08/01	2005/08/01	0
37	GP146	-53 376	-2 922 501	-2 922 501	1 550	1 550	1 550	1	1 550	1 550	0	Single Data Point	2005/08/02	2005/08/02	0
38	GP147	-53 378	-2 922 495	-2 922 495	1 552	1 552	1 552	1	1 552	1 552	0	Single Data Point	2005/08/02	2005/08/02	0
39	GP148	-55 389	-2 920 859	-2 920 859	1 583	1 583	1 583	1	1 583	1 583	0	Single Data Point	2005/08/01	2005/08/01	0
40	GP149	-62 238	-2 912 701	-2 912 701	1 570	1 570	1 570	1	1 570	1 570	0	Single Data Point	2005/08/03	2005/08/03	0
41	GP151	-54 251	-2 895 045	-2 895 045	1 579	1 579	1 579	1	1 579	1 579	0	Single Data Point	2005/08/06	2005/08/06	0
42	GP152	-54 367	-2 893 415	-2 893 415	1 580	1 580	1 580	1	1 580	1 580	0	Single Data Point	2005/08/07	2005/08/07	0
43	cen15	-70 873	-2 912 241	-2 912 241	1 553	1 553	1 553	1	1 553	1 553	0	Single Data Point	2005/09/28	2005/09/28	0
44	cen16	-70 997	-2 911 173	-2 911 173	1 555	1 555	1 555	1	1 555	1 555	0	Single Data Point	2005/09/28	2005/09/28	0
45	cen18	-72 021	-2 909 083	-2 909 083	1 588	1 588	1 588	1	1 588	1 588	0	Single Data Point	2005/09/28	2005/09/28	0
46	cen21	-72 346	-2 907 646	-2 907 646	1 595	1 595	1 595	1	1 595	1 595	0	Single Data Point	2005/09/28	2005/09/28	0
47	cen22	-72 062	-2 907 501	-2 907 501	1 598	1 598	1 598	1	1 598	1 598	0	Single Data Point	2005/09/28	2005/09/28	0
48	cen25	-73 423	-2 908 462	-2 908 462	1 587	1 587	1 587	1	1 587	1 587	0	Single Data Point	2005/09/28	2005/09/28	0
49	cen28	-73 607	-2 908 919	-2 908 919	1 592	1 592	1 592	1	1 592	1 592	0	Single Data Point	2005/09/28	2005/09/28	0
50	cen57	-61 570	-2 888 331	-2 888 331	1 545	1 545	1 545	1	1 545	1 545	0	Single Data Point	2005/09/28	2005/09/28	0
51	cen59	-61 451	-2 888 032	-2 888 032	1 595	1 595	1 595	1	1 595	1 595	0	Single Data Point	2005/09/28	2005/09/28	0
52	cen61	-60 971	-2 888 096	-2 888 096	1 599	1 599	1 599	1	1 599	1 599	0	Single Data Point	2005/09/28	2005/09/28	0
53	cen63	-60 800	-2 888 317	-2 888 317	1 562	1 562	1 562	1	1 562	1 562	0	Single Data Point	2005/09/28	2005/09/28	0
54	cen69	-64 052	-2 910 435	-2 910 435	1 579	1 579	1 579	1	1 579	1 579	0	Single Data Point	2005/09/28	2005/09/28	0
55	cen71	-63 037	-2 909 632	-2 909 632	1 608	1 608	1 608	1	1 608	1 608	0	Single Data Point	2005/09/28	2005/09/28	0
56	cen72	-63 176	-2 909 821	-2 909 821	1 583	1 583	1 583	1	1 583	1 583	0	Single Data Point	2005/09/28	2005/09/28	0
57	cen74	-63 833	-2 910 234	-2 910 234	1 582	1 582	1 582	1	1 582	1 582	0	Single Data Point	2005/09/28	2005/09/28	0
58	cen76	-63 674	-2 909 990	-2 909 990	1 603	1 603	1 603	1	1 603	1 603	0	Single Data Point	2005/09/28	2005/09/28	0
59	cen80	-64 282	-2 910 237	-2 910 237	1 586	1 586	1 586	1	1 586	1 586	0	Single Data Point	2005/09/28	2005/09/28	0
60	cen82	-63 194	-2 910 121	-2 910 121	1 577	1 577	1 577	1	1 577	1 577	0	Single Data Point	2005/09/28	2005/09/28	0
61	cen83	-63 265	-2 909 977	-2 909 977	1 576	1 576	1 576	1	1 576	1 576	0	Single Data Point	2005/09/28	2005/09/28	0
62	cen84	-62 745	-2 910 185	-2 910 185	1 604	1 604	1 604	1	1 604	1 604	0	Single Data Point	2005/09/28	2005/09/28	0
63	cen86	-62 432	-2 910 859	-2 910 859	1 598	1 598	1 598	1	1 598	1 598	0	Single Data Point	2005/09/28	2005/09/28	0
64	cen87	-62 432	-2 910 870	-2 910 870	1 598	1 598	1 598	1	1 598	1 598	0	Single Data Point	2005/09/28	2005/09/28	0
65	cen88	-62 382	-2 910 859	-2 910 859	1 562	1 562	1 562	1	1 562	1 562	0	Single Data Point	2005/09/28	2005/09/28	0
66	cen92	-63 125	-2 912 015	-2 912 015	1 566	1 566	1 566	1	1 566	1 566	0	Single Data Point	2005/09/28	2005/09/28	0
67	cen94	-62 427	-2 911 945	-2 911 945	1 588	1 588	1 588	1	1 588	1 588	0	Single Data Point	2005/09/28	2005/09/28	0
68	cen102	-59 922	-2 896 433	-2 896 433	1 599	1 599	1 599	1	1 599	1 599	0	Single Data Point	2005/09/28	2005/09/28	0
69	cen103	-59 434	-2 895 977	-2 895 977	1 600	1 600	1 600	1	1 600	1 600	0	Single Data Point	2005/09/28	2005/09/28	0
70	cen105	-59 634	-2 895 956	-2 895 956	1 601	1 601	1 601	1	1 601	1 601	0	Single Data Point	2005/09/28	2005/09/28	0
71	cen120	-57 001	-2 887 579	-2 887 579	1 596	1 596	1 596	1	1 596	1 596	0	Single Data Point	2005/09/28	2005/09/28	0
72	cen125	-58 277	-2 888 615	-2 888 615	1 600	1 600	1 600	1	1 600	1 600	0	Single Data Point	2005/09/28	2005/09/28	0
73	cen126	-59 434	-2 895 977	-2 895 977	1 605	1 605	1 605	1	1 605	1 605	0	Single Data Point	2005/09/28	2005/09/28	0
74	cen130	-59 141	-2 890 104	-2 890 104	1 600	1 600	1 600	1	1 600	1 600	0	Single Data Point	2005/09/28	2005/09/28	0
75	cen132	-59 270	-2 890 271	-2 890 271	1 604	1 604	1 604	1	1 604	1 604	0	Single Data Point	2005/09/28	2005/09/28	0
76	cen133	-58 376	-2 886 755	-2 886 755	1 604	1 604	1 604	1	1 604	1 604	0	Single Data Point	2005/09/28	2005/09/28	0
77	cen136	-59 850	-2 890 384	-2 890 384	1 610	1 610	1 610	1	1 610	1 610	0	Single Data Point	2005/09/28	2005/09/28	0
78	cen137	-59 839	-2 890 495	-2 890 495	1 608	1 608	1 608	1	1 608	1 608	0	Single Data Point	2005/09/28	2005/09/28	0
79	cen138	-59 598	-2 890 837	-2 890 837	1 610	1 610	1 610	1	1 610	1 610	0	Single Data Point	2005/09/28	2005/09/28	0

Site ID	Site ID	X LO_29	Y LO_29	Z (mamsl)	Average of Hydraulic Head (mamsl)	P95 of Hydraulic Heads (mamsl)	P50 of Hydraulic Heads (mamsl)	Number of Data Points (count)	First Measured Hydraulic Head (mamsl)	Last Measured Hydraulic Head (mamsl)	Difference (m)	Trend First to Last	First Measured Date	Last Measured Date	Record Span (years)
80	cen140	-59 487	-2 891 003	-2 891 003	1 606	1 606	1 606	1	1 606	1 606	0	Single Data Point	2005/09/28	2005/09/28	0
81	cen141	-59 007	-2 890 890	-2 890 890	1 601	1 601	1 601	1	1 601	1 601	0	Single Data Point	2005/09/28	2005/09/28	0
82	cen144	-60 823	-2 885 481	-2 885 481	1 620	1 620	1 620	1	1 620	1 620	0	Single Data Point	2005/09/28	2005/09/28	0
83	cen145	-59 682	-2 892 012	-2 892 012	1 616	1 616	1 616	1	1 616	1 616	0	Single Data Point	2005/09/28	2005/09/28	0
84	cen148	-59 865	-2 891 414	-2 891 414	1 601	1 601	1 601	1	1 601	1 601	0	Single Data Point	2005/09/28	2005/09/28	0
85	cen149	-59 915	-2 891 392	-2 891 392	1 619	1 619	1 619	1	1 619	1 619	0	Single Data Point	2005/09/28	2005/09/28	0
86	cen150	-60 050	-2 890 429	-2 890 429	1 612	1 612	1 612	1	1 612	1 612	0	Single Data Point	2005/09/28	2005/09/28	0
87	cen154	-63 957	-2 894 025	-2 894 025	1 558	1 558	1 558	1	1 558	1 558	0	Single Data Point	2005/09/28	2005/09/28	0
88	cen156	-64 012	-2 893 879	-2 893 879	1 594	1 594	1 594	1	1 594	1 594	0	Single Data Point	2005/09/28	2005/09/28	0
89	cen163	-62 300	-2 892 782	-2 892 782	1 625	1 625	1 625	1	1 625	1 625	0	Single Data Point	2005/09/28	2005/09/28	0
90	cen164	-62 255	-2 892 584	-2 892 584	1 596	1 596	1 596	1	1 596	1 596	0	Single Data Point	2005/09/28	2005/09/28	0
91	cen165	-62 255	-2 892 591	-2 892 591	1 630	1 630	1 630	1	1 630	1 630	0	Single Data Point	2005/09/28	2005/09/28	0
92	cen166	-62 251	-2 892 594	-2 892 594	1 601	1 601	1 601	1	1 601	1 601	0	Single Data Point	2005/09/28	2005/09/28	0
93	cen167	-61 948	-2 893 381	-2 893 381	1 628	1 628	1 628	1	1 628	1 628	0	Single Data Point	2005/09/28	2005/09/28	0
94	cen168	-61 694	-2 893 119	-2 893 119	1 633	1 633	1 633	1	1 633	1 633	0	Single Data Point	2005/09/28	2005/09/28	0
95	cen170	-61 935	-2 893 378	-2 893 378	1 631	1 631	1 631	1	1 631	1 631	0	Single Data Point	2005/09/28	2005/09/28	0
96	cen172	-67 050	-2 898 619	-2 898 619	1 624	1 624	1 624	1	1 624	1 624	0	Single Data Point	2005/09/28	2005/09/28	0
97	cen201	-74 251	-2 910 315	-2 910 315	1 459	1 459	1 459	1	1 459	1 459	0	Single Data Point	2005/09/28	2005/09/28	0
98	cen555	-60 628	-2 899 078	-2 899 078	1 576	1 576	1 576	1	1 576	1 576	0	Single Data Point	2005/09/28	2005/09/28	0
99	cen592	-68 533	-2 921 974	-2 921 974	1 571	1 571	1 571	1	1 571	1 571	0	Single Data Point	2005/09/28	2005/09/28	0
100	cen603	-74 910	-2 916 787	-2 916 787	1 516	1 516	1 516	1	1 516	1 516	0	Single Data Point	2005/09/28	2005/09/28	0
101	cen604	-74 446	-2 916 298	-2 916 298	1 514	1 514	1 514	1	1 514	1 514	0	Single Data Point	2005/09/28	2005/09/28	0
102	CEN680	-61 510	-2 898 989	-2 898 989	1 576	1 576	1 576	1	1 576	1 576	0	Single Data Point	2005/09/28	2005/09/28	0
103	CEN681	-54 146	-2 899 878	-2 899 878	1 577	1 577	1 577	1	1 577	1 577	0	Single Data Point	2005/09/28	2005/09/28	0

*Shaft Locations marked | blue

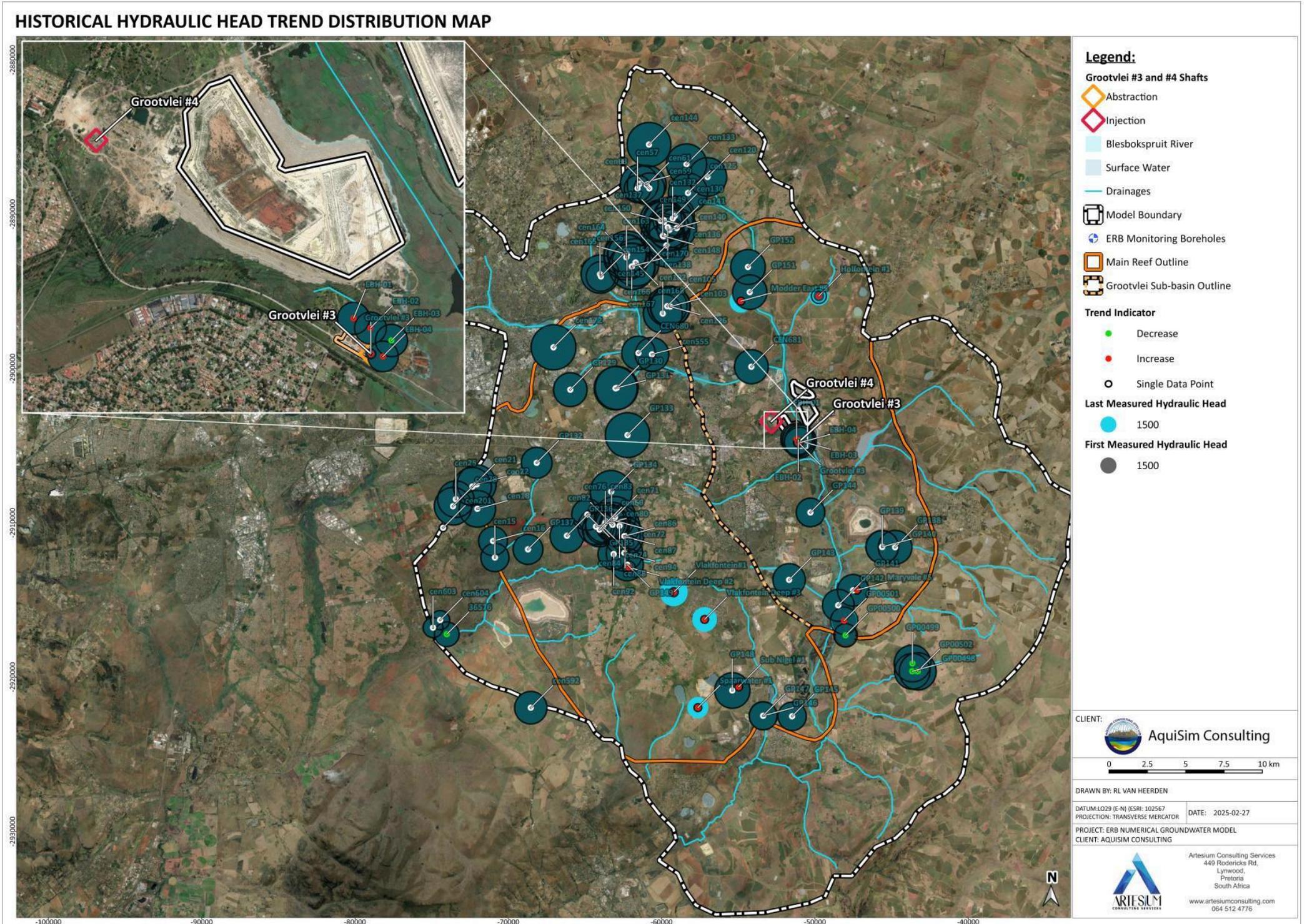


Figure 3-5: Historical Hydraulic Head Trend Distribution Map

3.5 Surface Water Quality Trends and Spatial Distribution

3.5.1 AMD and Effluent Water

Water quality of AMD samples that have been taken from the abstracted water at Grootvlei #3 shaft had stable TDS (Total Dissolved Solids) concentrations. From the TDS values to date, 80% were between 2 034 mg/L and 2 361 mg/L. For sulphate 80% of values were between 968 mg/L and 1 247 mg/L. Although sulphate in plant effluent have varied from being 35% below that of AMD to 21% above, the averages for AMD and effluent are not distinguishable. On average, ERB plant effluent TDS has been 5% lower than AMD TDS.

Variation in AMD iron concentrations observed to date were in contrast with the relative stability of other parameters. The long-term average concentration of 11 mg/l includes concentrations below the detection limit up to elevated concentrations of which 10% were above 41 mg/l (maximum of 82 mg/l). The reasons for the variations may relate to a defined interface between water of different qualities and properties that have been noted at depths that varied between 130 m and 160 m and is near the pump intake (Exigo, 2020). The only other AMD parameters with similar variations are turbidity and suspended solids. In contrast to iron concentrations in the AMD, the iron concentrations in plant effluent have not exceeded 0.3 mg/l and was only detected in 5% of samples taken. Average iron concentration of 11 mg/L in AMD decreasing to below 0.004 mg/l in plant effluent implies that 780 kg/d of iron is disposed (Grootvlei #4 shaft) via the sludge injection, given abstraction and treatment of 71 ML/d.

Manganese is detected constantly in the AMD water and in a relatively narrow range. In monitoring to date, 80% of concentrations were between 2.5 mg/L and 4.4 mg/L and averaged 3.436 mg/L. Manganese in plant effluent has averaged 2.044 mg/L since April 2020. The decrease in concentration implies that 100 kg/d of manganese is disposed of via the sludge.

Uranium was below detection (0.015 mg/L) in most samples taken in the shaft from July 2017 to March 2019. Uranium in the five AMD abstraction samples taken from April 2019 to May 2020 averaged 0.043 mg/L. Uranium was then below detection in twelve samples taken, only detected again on 21 February 2023 at 0.028 mg/L and recently during November 2024 (0.021 mg/L). The detection of U in AMD water seems to be related to the detection of U in plant effluent samples at times. The November 2024 concentrations in AMD water and effluent of 0.021 mg/L also matched exactly. This would imply minimal uranium was disposed of via the sludge and rather goes through plant processes and is deposited into the Blesbokspruit River. It is recommended that the plant SOP is adapted to remove U from the abstracted AMD water.

In AMD, effluent and surface water samples taken on 30 January 2025 uranium was below the detection limit of 0.015 mg/L using the regular ICP-OES method. Samples were however also subjected to ICP-MS analyses and results of 0.016 mg/L (effluent) and 0.009 mg/L (AMD) were obtained. At surface water upstream locations ESW-01, ESW-02 and ESW-04 uranium was not detected. Downstream at ESW-06, uranium of 0.003 mg/L was detected.

At the Central Basin plant, a sample of sludge was taken during a spillage on 29 July 2023. Uranium was not detected in either the water fraction or the leachate of the solids fraction (Artesium, 2023). Together with the above, this corroborates minimal disposal of uranium via the sludge injection.

3.5.2 Surface Water Quality

Water quality of the Blesbokspruit and tributary has been monitored since inception of the plant in 2015. Six locations have been sampled (refer to Figure 3-6). Significant impact due to plant effluent discharge has been observed at the downstream locations ESW-03 and ESW-06. These locations are approximately 700 m and 1.7 km downstream of the plant, respectively. The impact at these locations has been characterised by elevated sulphate concentrations and 80% of values have been between 139 mg/L and 660 mg/L, at times of effluent discharge. In contrast, at the upstream locations ESW-01, ESW-02 and ESW-04, 80% of sulphate concentrations have been between 37 mg/L and 117 mg/L.

The increase in sulphate concentrations from upstream to downstream of plant discharge has been balanced by associated increases in calcium and magnesium concentrations and to a lesser extent sodium. No other increases were observed. Specifically, average iron and manganese concentrations were noted to decrease from upstream to downstream. Impact by sludge would likely reflect in increase in iron concentrations.

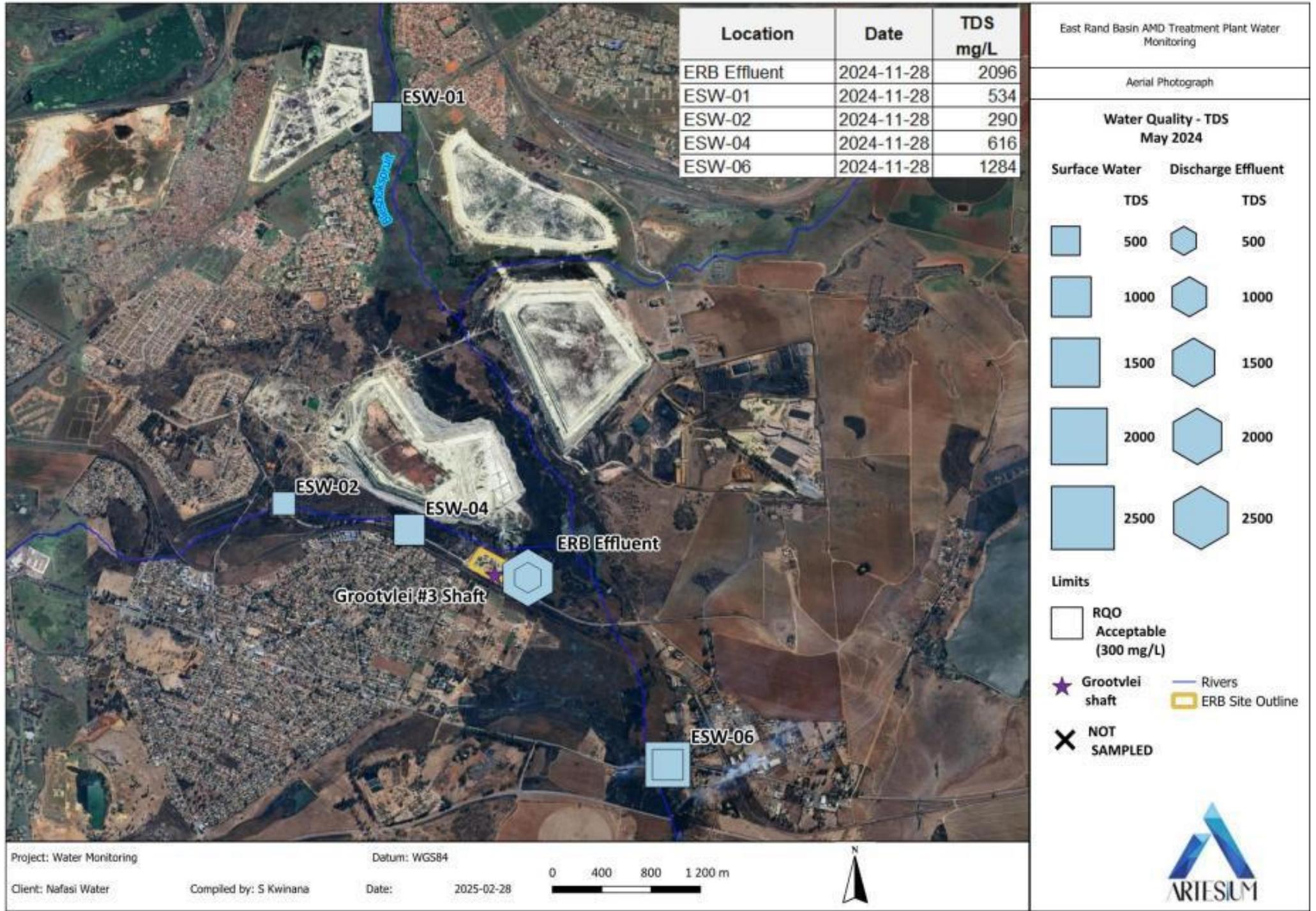


Figure 3-6: ERB TDS Surface Water Quality Results for February 2025

3.5.3 Plant Groundwater Quality

In the ERB plant environmental authorisation (DEA, 2013) under Specific Conditions, Water Quality Monitoring (Item 59), a requirement for installation of shallow monitoring wells around the treatment facility is made. The drilling of four boreholes on the perimeter of the plant in 2015 was in fulfilment of this requirement.

Groundwater quality has not been observed to change significantly over time. An initial TDS of 2 040 mg/L and two values near 1 500 mg/L during 2017 were observed at ERB-01. All other values at ERB-01, ERB-02 and ERB-03 were below 600 m/L. Boreholes EBH-04 has maintained a slightly higher TDS not values have never exceeded 850 mg/L. TDS values during November 2024 varied from 276 mg/L (EBH-01) to 544 mg/L (EBH-04). See Figure 3-7.

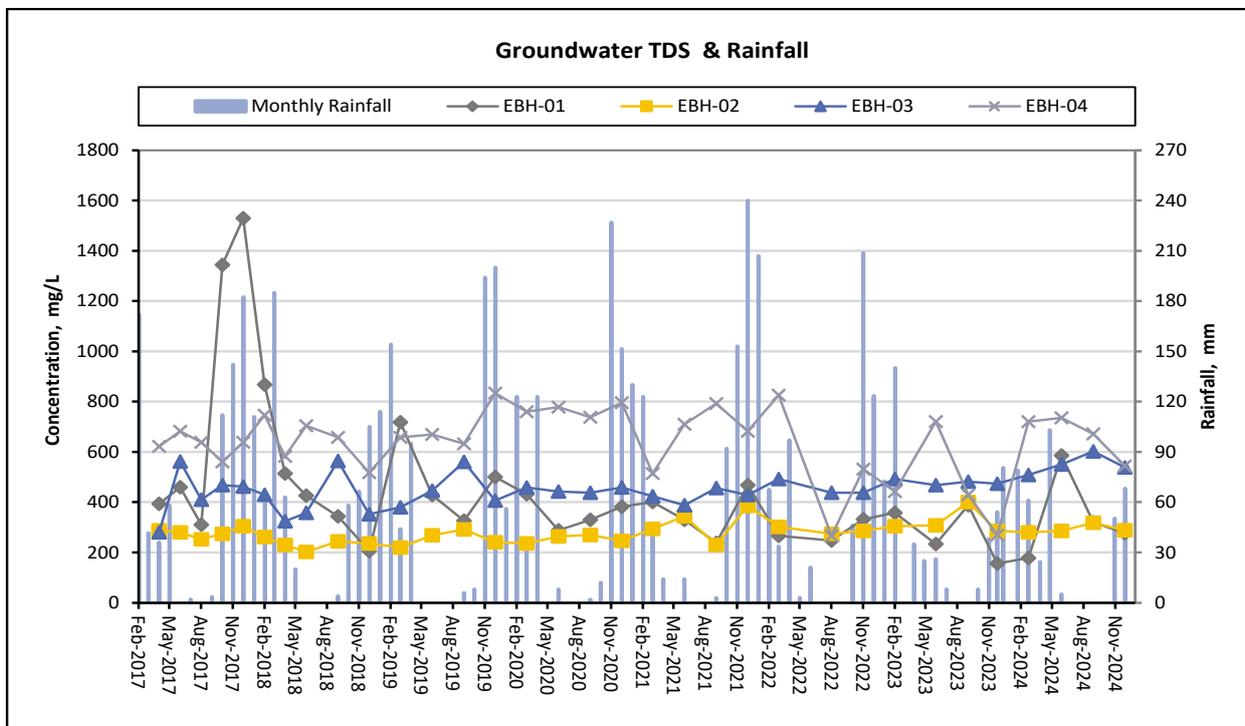


Figure 3-7: Groundwater TDS Trends vs Rainfall Trends

Three metals (iron, manganese and uranium) were identified as critical for monitoring. In terms of these metals the following was noted.

Manganese was detected at EBH-01 (0.02 mg/L), EBH-03 (0.16 mg/L) and EBH -04 (0.24 mg/L) during November 2024. It was not detected at EBH-02. Iron and uranium were not detected at any borehole. These results were similar to historical findings as manganese has been detected in 70% of groundwater samples to date. Only five (2.6%) of these manganese values have exceeded the SANS 241 drinking water limit of 0.4 mg/L and all five instances were before 2018. Iron has been detected in 15% of groundwater samples to date. Only five (2.6%) of these iron values have exceeded the SANS 241 drinking water limit of 2 mg/L and these were sporadically at EBH-01 and EBH-03. Uranium has only been detected in 1 out of 180 groundwater

samples taken to date and this was during 2015. In view of the above results, it was inferred that no impact on groundwater was observed from sludge or AMD water.

3.5.4 DWS Groundwater Database Quality

Groundwater quality data for the area of interest was requested from DWS. A data set for 924 boreholes, mostly located west of the model boundary as far as Rockville, was received. The data dates back to 1970, with 80% of the data covering the years 1983 to 1999. It included five boreholes that are located within the model boundary and also have results for 2024. Seventy other boreholes are located within the model boundary with data older than 1995.

TDS and sulphate concentrations for the five boreholes within the model boundary and with recent results are listed in Table 3-3. These boreholes are less than 7 km apart and located between 1 km and 7 km from the Blesbokspruit (refer to Figure 3-9), and some 10 km south of the ERB plant. Four of the boreholes displayed similar quality in their available data, that covers July 2022 to June 2024. TDS for these boreholes varied between 421 mg/L and 753 mg/L, while sulphate varied between 7 mg/L and 325 mg/L.

At the fifth borehole (1000265505), TDS values varied between 1 580 mg/L and 3 330 mg/L, with elevated sulphate averaging 1 457 mg/L. The borehole is located at the Maryvale mine shaft #5 and likely affected by local historical mining activities. The higher TDS and sulphate concentrations correlates with AMD water and this could also be indicative of the borehole being drilled into the ERB, accessing AMD water.

Table 3-3: TDS and sulphate for five boreholes in DWS data set

DWS Borehole ID	Date Analysed	Total Dissolved Solids as TDS [mg/L]	Sulphate as SO ₄ [mg/L]
1000265488	2024/06/11	677	78
1000265496	2024/06/11	623	80
1000265499	2024/06/11	452	39
1000265501	2024/06/11	565	14
1000265505	2024/03/11	1 570	1 143

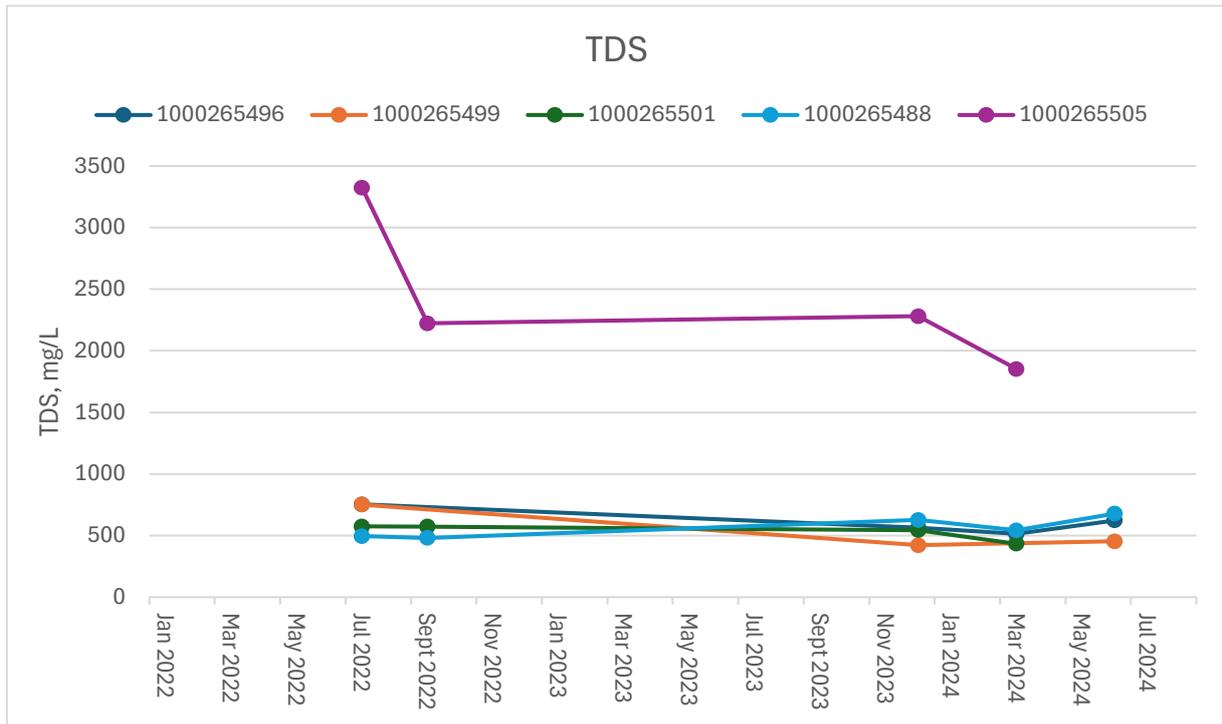


Figure 3-8: TDS for five boreholes in DWS data set.

In terms of the three metals (iron, manganese and uranium) identified as critical for monitoring, the following was noted:

- Iron concentrations at the five boreholes (1000265488, 1000265496, 1000265499, 1000265501, and 1000265505) were all below 0.07 mg/L, well below the SANS 241 drinking water limit of 2 mg/L. No discernible trends were observed.
- Manganese concentrations at borehole 1000265505 (at Maryvale #5 shaft) varied between 2.65 mg/L and 4.2 mg/L and exceeded the SANS 241 drinking water limit of 0.4 mg/L. One concentration of 0.68 mg/L at 1000265496 during July 2022 also exceeded the limit. Subsequent concentrations as well as concentrations at three other boreholes were while below 0.03 mg/L. No uranium results were available in the data set.
- In view of the above results, it was inferred that no impact on groundwater was observed from sludge or AMD water.

DWS GROUNDWATER TDS BUBBLE PLOT DISTRIBUTION MAP

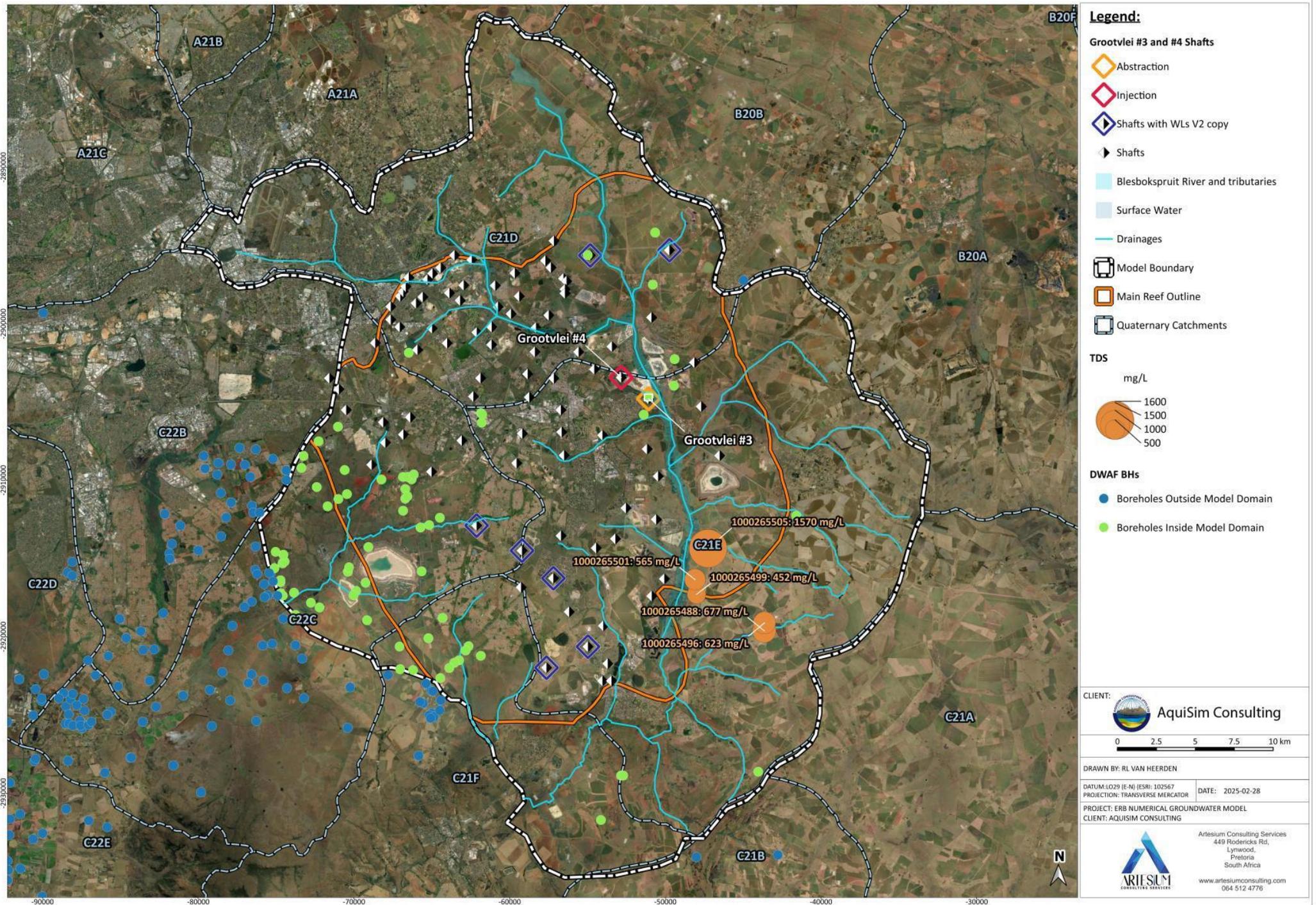


Figure 3-9: Groundwater TDS Bubble Plot Distribution Map

4 AQUIFER CHARACTERISATION

The aquifer classification and vulnerability were assessed using the aquifer system management classification discussed in Parsons and Conrad’s (1995) Explanatory Note for the Aquifer Classification Map of South Africa. The aquifer vulnerability and classification maps are presented in Figure 4-1 and Figure 4-2,

The aquifer system management classification was developed based on the work by Parsons (1995) and Vegter (1995). The aquifer classification map was developed utilising the geohydrological units developed by Vegter (1995) and system management classes developed by Parsons (1995). Table 4-1 below presents the different aquifer classes as described by Parsons and Conrad.

Table 4-1: Modified aquifer system management classification (Parsons and Conrad, 1995)

Aquifer type	Description
Sole source aquifer	An aquifer used to supply 50% or more of urban domestic water for a given area and for which there are no reasonably available alternative sources of water.
Major aquifer region	A high-yielding aquifer system of good quality water.
Minor aquifer region	A moderately-yielding aquifer system of variable water quality.
Poor groundwater region	A low to negligible yielding aquifer system of moderate to poor water quality.
Special aquifer region	An aquifer system designated as such by the Minister of Water Affairs and Forestry, after due process.

Table 4-2 below indicates groundwater usage in South Africa and was developed to inform the sole source aquifers and special aquifers across the country.

Table 4-2: The Aquifer Management System in Relation to The Borehole Prospect Map Of Vegter (1995) and (Parsons & Conrad, 1995)

Accessibility	Exploitability					
	<10%	10% - 20 %	20% - 30 %	30% - 40 %	40% - 50 %	>50%
>60%	poor	minor	minor	major	major	major
40% - 60%	poor	poor	minor	minor	major	major
<40%	poor	poor	poor	minor	minor	major

Q and TQc	major
-----------	-------

The Aquifer vulnerability is based on the map originally compiled by Reynders and Lynch (1993), (Parsons & Conrad, 1995). The classification uses the DRASTIC method of classification that considers the seven factors that affect aquifer characterization:

1. Depth to groundwater;
2. Recharge;
3. Aquifer Media;

4. Soil media;
5. Topography;
6. Impact on vadose zone; and
7. (Hydraulic) Conductivity.

The ERB watershed is inferred to be underlain by a major aquifer system. Considering the Aquifer Vulnerability of South Africa Map (2013) the aquifer region is rated as most vulnerable. Aquifer mass susceptibility can be determined by the product of the classification and vulnerability of an aquifer. The matrix in Table 4-3 shows the different classes in aquifer susceptibility. Based on the description given in the table, the localized aquifer underlying the plant has high susceptibility to mass transport.

Table 4-3: Aquifer Contamination susceptibility classes (Parsons & Conrad, 1995)

Vulnerability Class	Vulnerability Class		
	low (1)	medium (2)	high (3)
Aquifer System Management Class			
poor groundwater region (1)	low susceptibility (1)	low susceptibility (2)	medium susceptibility (3)
minor aquifer region (2)	low susceptibility (2)	medium susceptibility (4)	high susceptibility (6)
major aquifer region (3)	medium susceptibility (3)	high susceptibility (6)	high susceptibility (9)

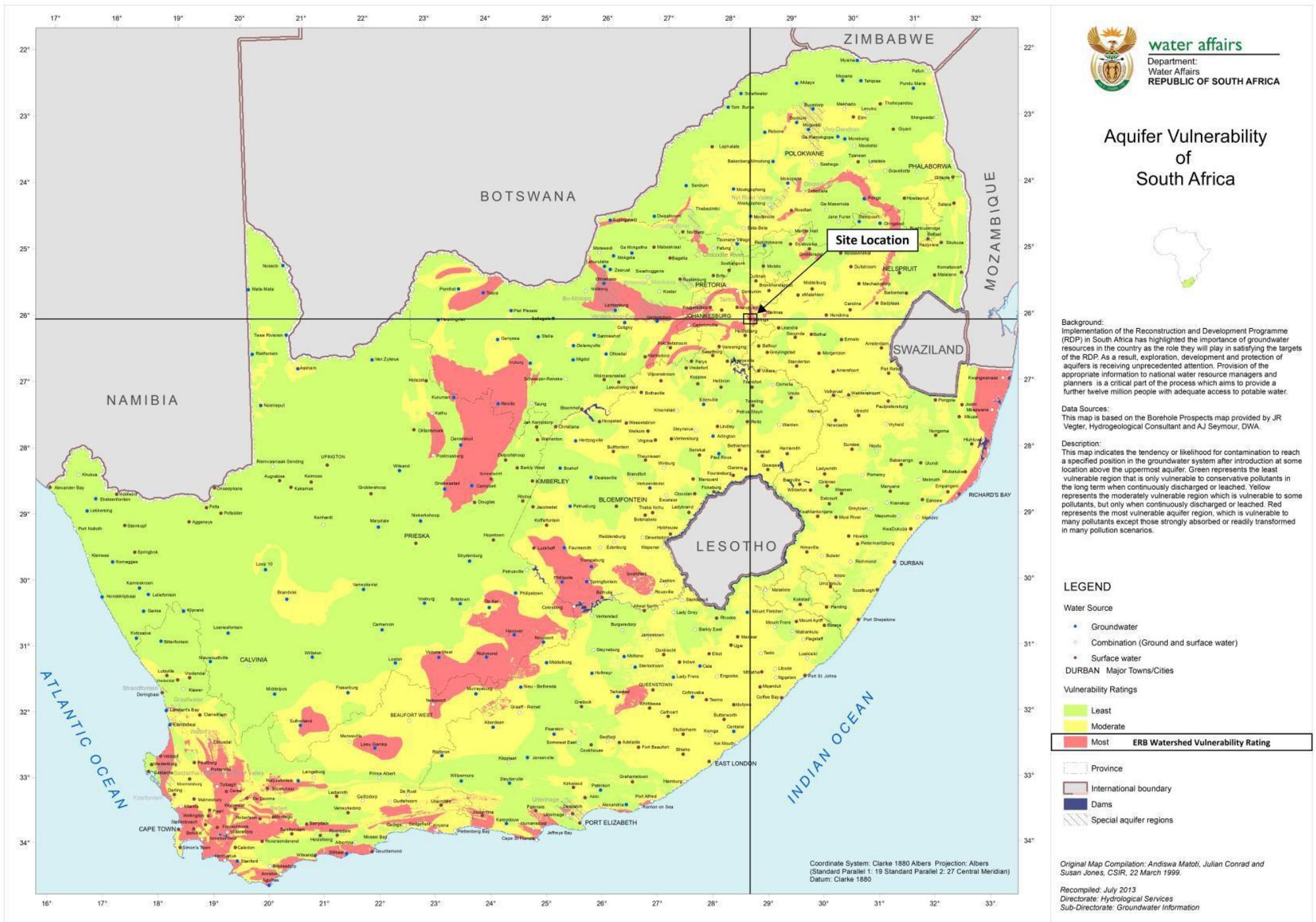


Figure 4-1: Aquifer Vulnerability Map of South Africa

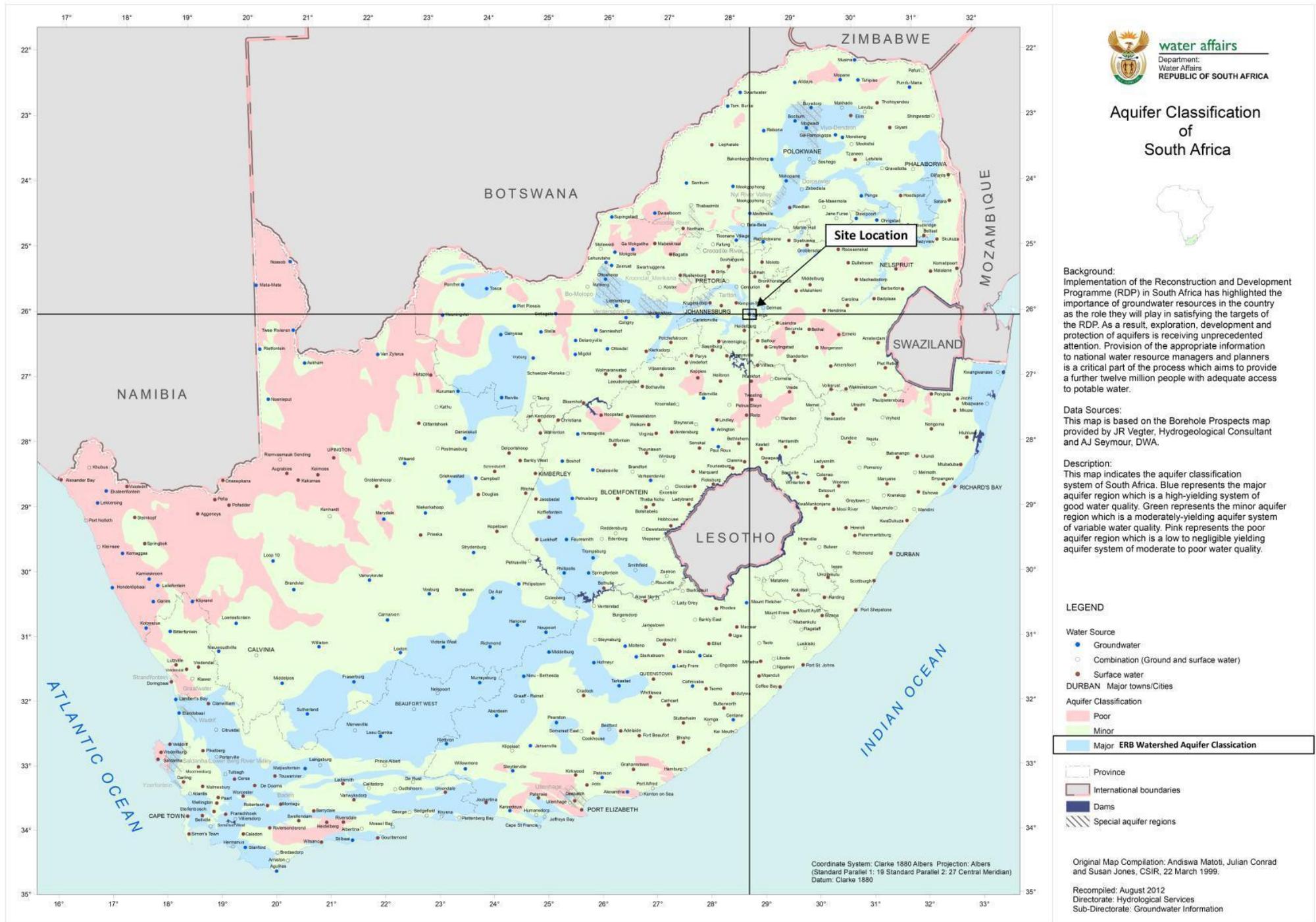


Figure 4-2: Aquifer Classification Map of South Africa

5 HYDROGEOLOGICAL CONCEPTUAL MODEL

A Conceptual Site Model (CSM) was constructed for the ERB delineated sub-catchment (model domain). The CSM displayed in Figure 5-2, with the model domain displayed in Figure 5-1. The following data sources were used to construct model:

- Model topography data was derived from the 1:50 000 topographical map series data of South Africa and the generated Digital Elevation Model (DEM).
- Surface geology and cross sections were derived from the 1:50 000 CGS map sheets (2628AB, 2628AD, 2628BA, and 2628BC), along with the explanation sheets compiled by Lubbe et al., (2007) and Opperman et al., (2005).
- The following data was gathered from reports compiled by AGES, 2006; Exigo 2017; ASA, 2022:
 - previous conceptual models;
 - model layer thickness and hydrogeological property zones;
 - ingress zones;
 - model groundwater and surface water balance volumes;
 - shaft locations and depths; and
 - groundwater recharge values.
- Main reef elevation, and green sill (grid) files from ACS archives.
- Climate data was derived from ACS archives and was recorded on site and provided by Nafasi Plant.
- Hydrochemistry data was summarised from ACS archives, that conducts the monthly monitoring at the plant.

The shape of the ERB was derived from ACS archives along with the Green Sill geometry. The Main Reef had a thickness of 1 m in the model, the Kimberley reef was simulated 500 m above the Main Reef and had the same thickness and hydraulic conductivity assigned to Main Reef. The main reef was represented in the model up to the surface with higher hydraulic conductivity values, as this reef is well developed, and it is assumed to be mined out up to or close to the surface.

The green sill was represented throughout the model domain as an impermeable layer as it is not known where the aquitard will pinch out or outcrop. The dykes in the model domain had an impermeable matrix with the contact zones input as preferential flow pathways utilising discrete features with a thickness of 0.1 m. Three other main flow pathways from surface to deep underground (Witwatersrand Supergroup) were represented in the model domain:

1. Shaft annulus (imposed as a discrete feature);
2. Main Reef outcrop (represented by higher K-values); and
3. Sinkholes underlain by WAD (Weathering After Dolomite input into the model with higher K-values).

The shallow mined out voids or footprint of mined out areas is not known. It was assumed that the dolomites underlying the sinkholes located to the east of the ERB plant would act as an ingress zone and recharge the Witwatersrand Supergroup, and both reefs. The water discharges from the Blesbokspruit at approximately 60 740 m³/d and accounts for 85% of the water pumped from the Grootvlei #3 shaft in the model. It is recommended that the mined-out areas be investigated in order to get a more accurate representation of ingress zones in the ERB.

The goal of the numerical groundwater model was to simulate the interaction or flow dynamics in the Grootvlei Sub-basin as a result of the injection at Grootvlei #4 shaft, and the dewatering from the Grootvlei #3 shaft. This was done to better understand the flow dynamics in the basin, especially the Grootvlei sub-basin.

Water quality of AMD samples that have been taken from the abstracted water at Grootvlei #3 shaft had a TDS concentration between 2 034 mg/L and 2 361 mg/L. The water quality of the injected sludge water was not known, and was estimated at approximately 1 500 mg/L. The estimate was calculated by comparing the liquid phase of the sludge from the Central Rand Basin (CRB) that had a TDS of 2 672 mg/L, and sulphate concentration of 1 635 mg/L (sampled 29 July 2023), with the effluent disposed on the same day that had a TDS concentration of 3 712 mg/L, and sulphate of 2 328 mg/L. ERB effluent has a typical TDS of 2 100 mg/L, and sulphate of 1 050 mg/L. Given, 2 672 mg/L (CRB sludge) divided by 3 712 mg/L (CRB effluent) times the average ERB effluent (2 100 mg/L), ERB TDS sludge mass load equals 1 500 mg/L.

A mass tracer load of 1 000 mg/L was injected as a transient mass tracer plume from Grootvlei #4 shaft. A mass tracer plume was considered as currently the sludge deposited into the #4 shaft had TDS concentrations that are lower than the in-situ AMD water in the Basin (refer to Section 3.5.1). The tracer mass plume of 1 000 mg/L was therefore used for simulations with a background (model domain) concentration of 0 mg/L. This would give the best representation of flow dynamics in the basin.

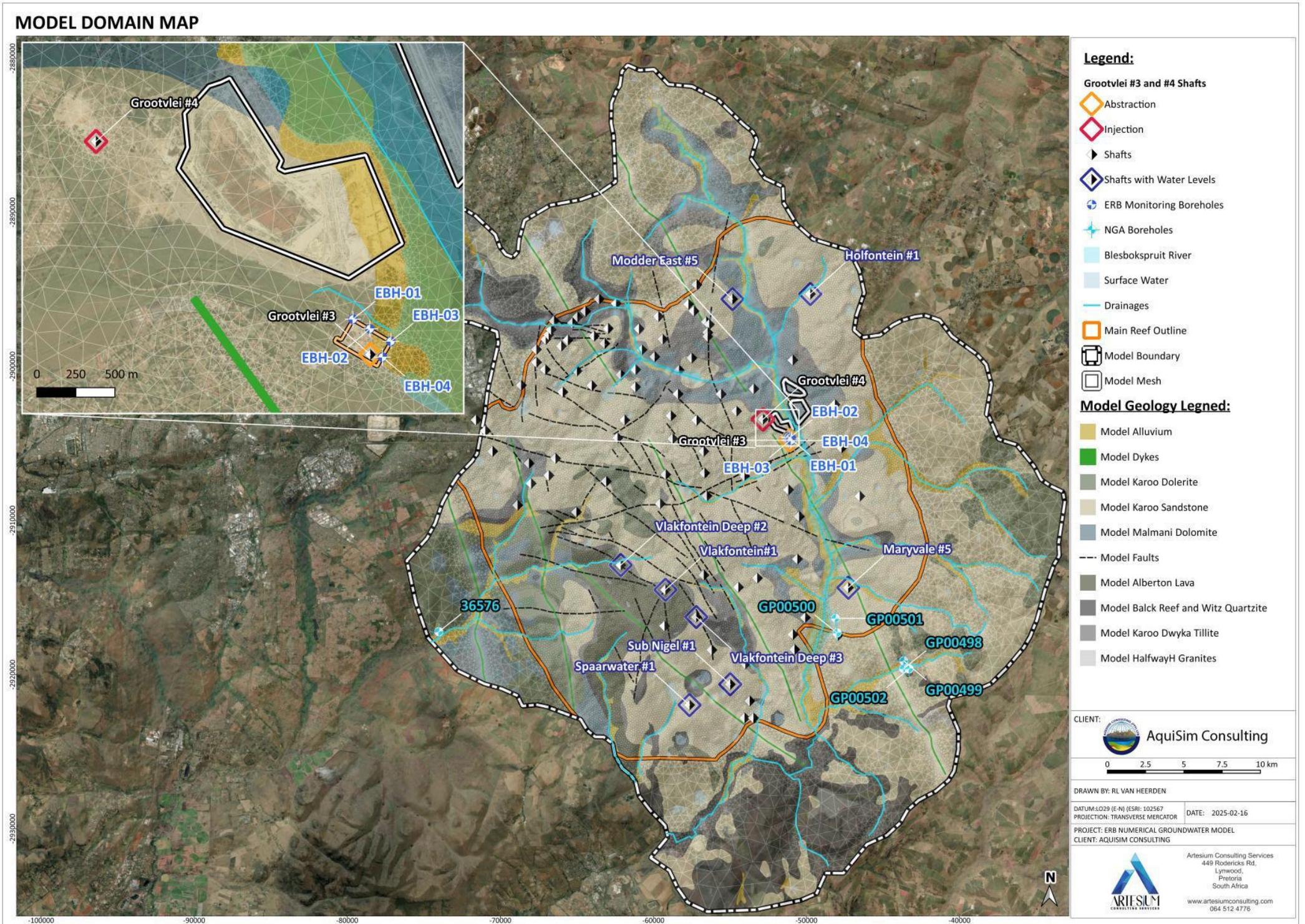
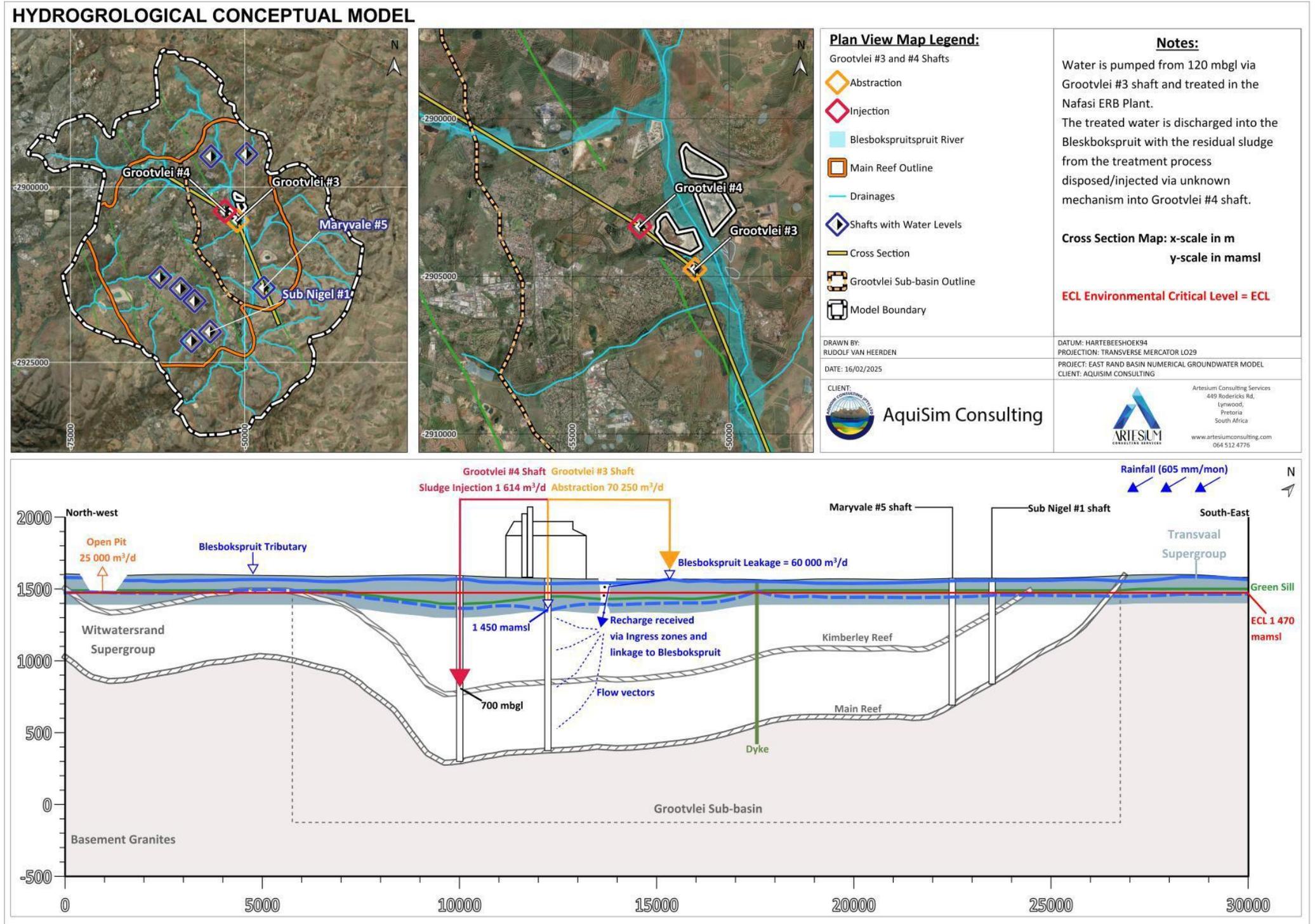


Figure 5-1: Model Domain Map



6 GROUNDWATER NUMERICAL MODEL

The main goal of project was to update the previous numerical model (ACS, 2006) with the latest available monitoring data in order and simulate flow dynamics between the dewatering and injection from Grootvlei #3 and Grootvlei #4 shafts, respectively. The modelling methodology and scenarios is shown in Figure 6-1. The Steady State (SS) and Transient State (TS) calibration discussion is attached in Appendix A, Section 10.

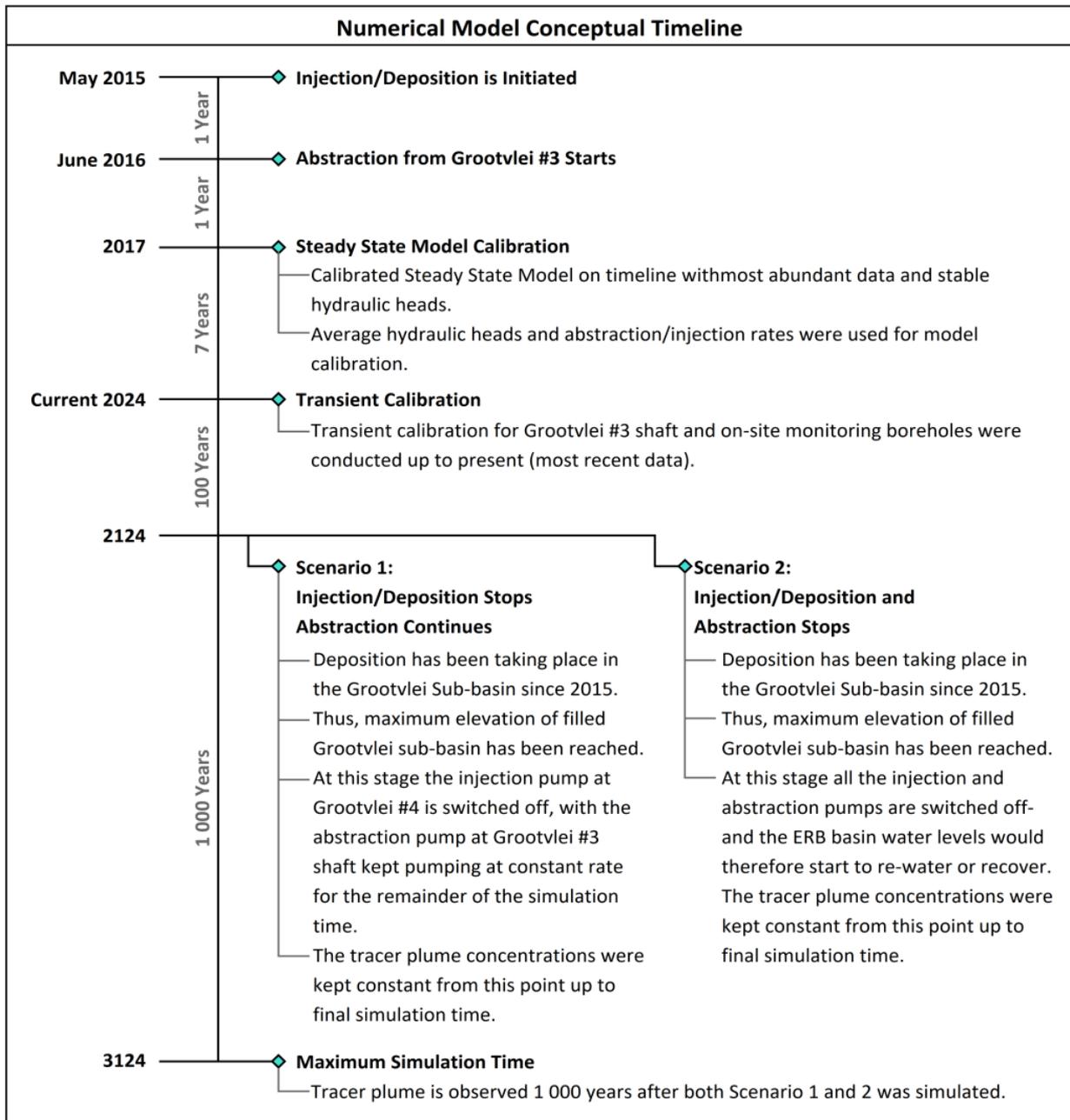


Figure 6-1: Conceptual Model Timeline

6.1 Source Term Analytical Model

An analytical model was prepared to define the source term (geometry) for the Grootvlei sub-basin as shown in Figure 6-1 and Figure 6-2. The analytical model was prepared by sequencing the deposition data on record (from March 2015 to December 2024) and comparing the cumulative deposited volume against the available volume calculated for Main Reef (Grootvlei sub-basin). The volume for Main Reef was calculated assuming a void space of 70%.

The total volume of liquid and solid phase sludge deposited up to date is equal to 75 944 m³, assuming a solid to liquid ratio of 1:10 (i.e. 10% is solids). This volumetric ratio was estimated from a sludge sample collected from the ERB plant.

The total volume for main reef was computed at 259 938 078 m³, given a void space of 70% the available space for deposition will be 181 956 655 m³. Currently the main reef is filled up to approximately 276 mamsl (0.2% capacity) assuming 616 440 m³ (999 t) of sludge solids have been deposited up to date.

After sequencing the deposition rate for 100 years (from March 2015 to March 2115) the total filled volume was calculated at 6 254 345 m³ (821 820 t), filled up to an elevation of 335 mamsl as depicted in Figure 6-2. The spillway depicted in Figure 6-2 is the lowest point in the ridge along the south-western side of the Grootvlei sub-basin. This was assumed as the highest point that the sub-basin could be theoretically filled up to. The current surface area for the source was calculated at 192 ha in the reef with the source growing up to a 1 001 ha after 100 years of deposition, given current deposition rates is sequenced. The source term was simulated according to this growth factor spatially in the simulated groundwater model.

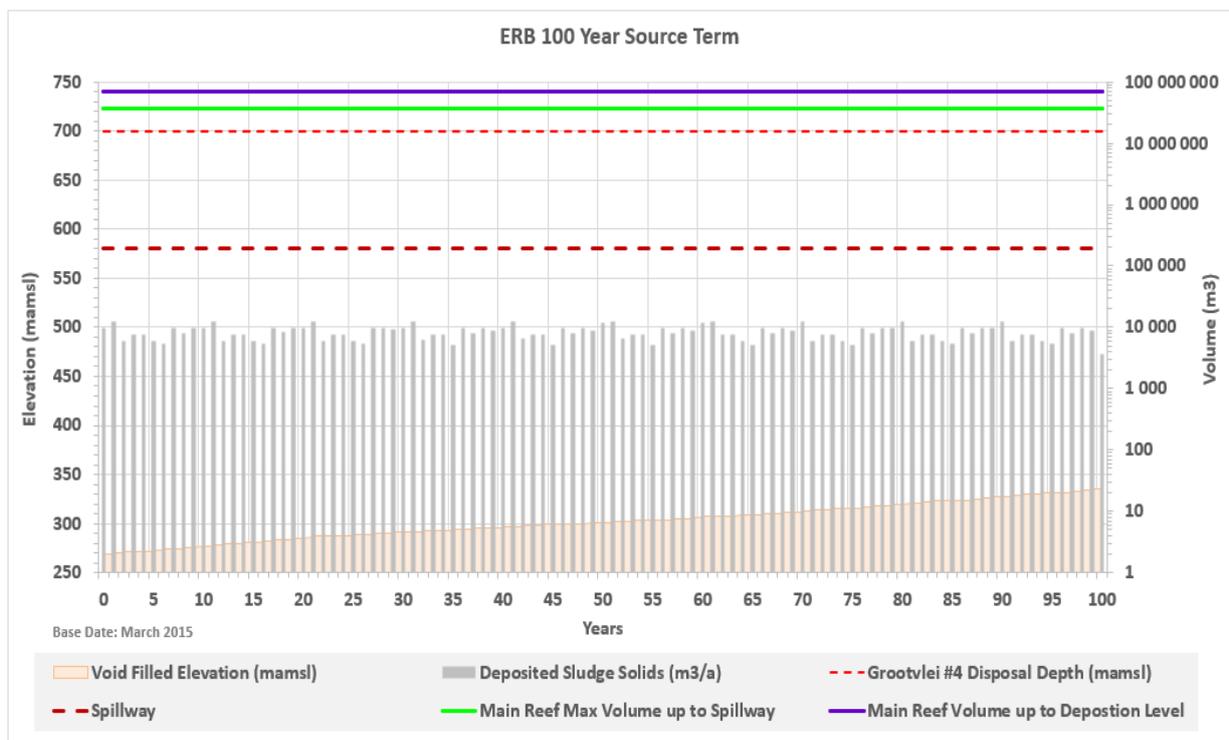


Figure 6-2: ERB 100 Year Source Term Analytical Model

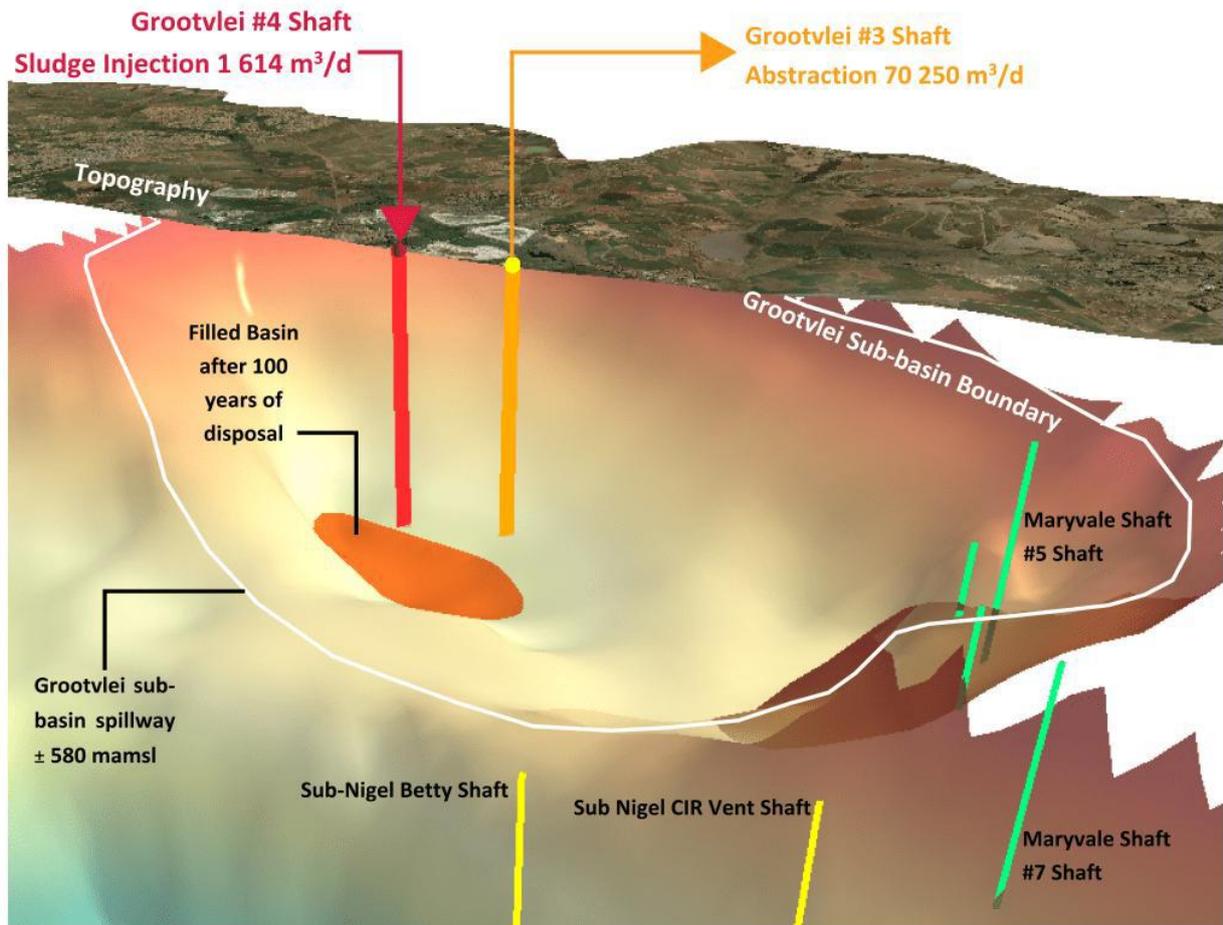


Figure 6-3: Grootvlei Sub-basin Filled Volume After 100 Years Of Simulated Deposition

6.2 Simulated Tracer Mass Plume – Scenario 1

In Scenario 1 the mass tracer was simulated to be deposited as detailed in Section 6.1. The surface area along which the 1 000 mg/L source was added in the model simulations was forward simulated up to 100 years. In order to represent the disposal ending after 100 years. The injection into Grootvlei #4 shaft was then stopped and the dewatering in Grootvlei #3 shaft was kept constant up to a 1 000 years. The resulting mass plume is shown in cross-section and zoomed plan view in Figure 6-4 and Figure 6-5. The simulated steady state flow particle tracking from the Blesbokspruit River footprint to the Abstraction point (Grootvlei #3 shaft) is shown in Figure 6-6.

A hundred years after deposition the tracer plume at the maximum extends approximately 3 430 m to the south-east and approximately 1 000 m upward from the injection point. The upwards extension of the tracer plume can be attributed to the injection taking place from the Witwatersrand Supergroup down towards the Main Reef. The method of injection/deposition was therefore considered conservative as the deposition would in reality take place from the Kimberley Reef downwards, and possibly from the Main Reef downwards. The centre of the tracer plume (1 000 mg/L) was considered to be at the Main Reef elevation. No decant was observed in the Scenario 1 simulation and the plume remained stagnant in place considering the 100 mg/L plume contour.

MASS TRACER PLUME SPATIAL EXTEND - 100 YEAR SIMULATION

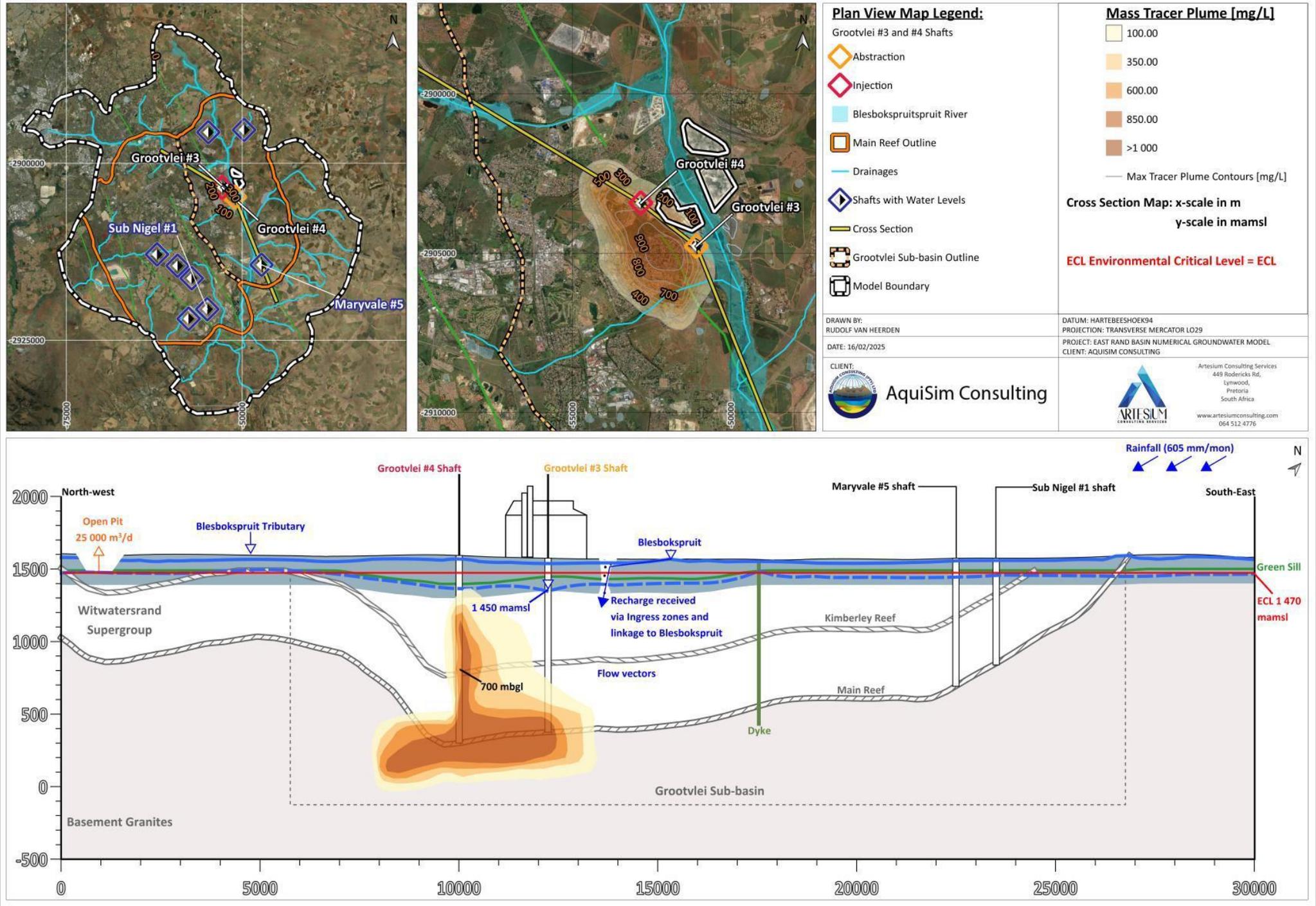


Figure 6-4: Transient Mass Tracer Simulated Plume Results - 100 Years Post Deposition for Scenario 1

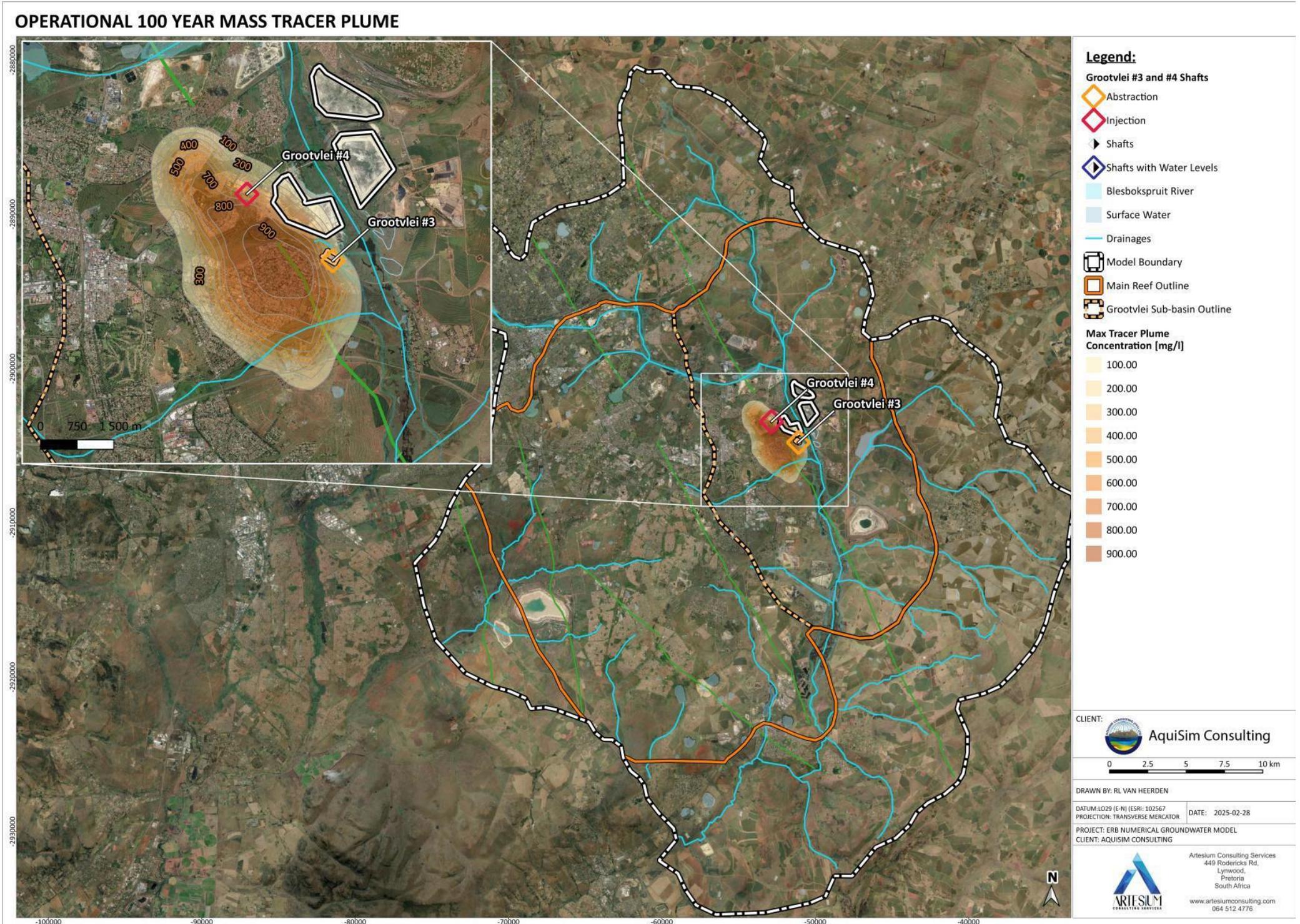


Figure 6-5: Transient Mass Tracer Simulated Plume Results - 100 Years Post Deposition for Scenario 1 – Zoomed in Spatially

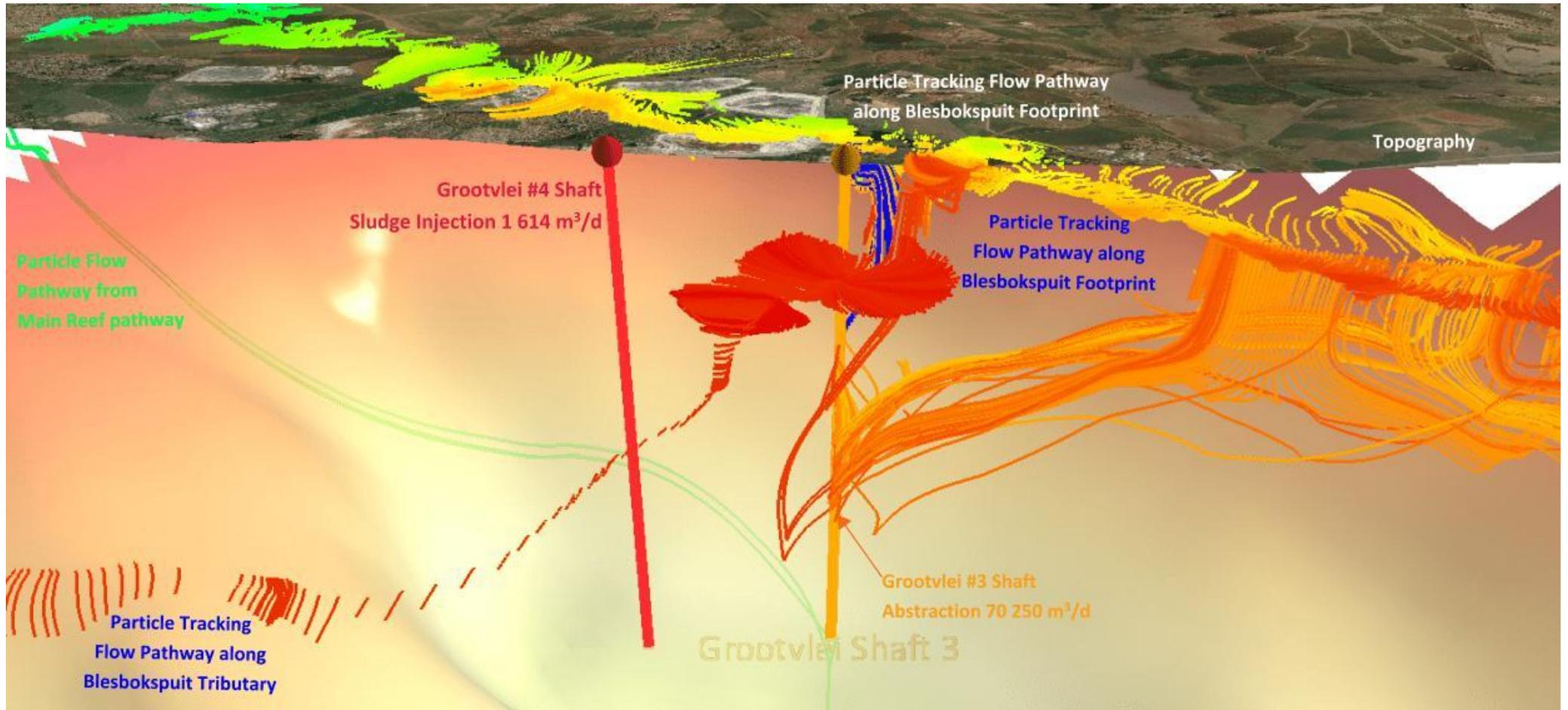


Figure 6-6: Particle Tracking Flow Pathway from Blesbokspuit to Witwatersrand Basin

6.3 Simulated Tracer Mass Plume – Scenario 2

For Scenario 2 the abstraction from Grootvlei #3 shaft was switched off to simulate the possible dereliction of the ERB Plant and subsequently the deposition of sludge was also simulated to stop. After a 1 000 years post deposition the tracer plume had a maximum plume extent of 23 x 10 km. From the disposal zone, the furthest tracer concentration was mapped at 16 km to the south-east of the site.

The plume followed the bathymetry of the Main Reef and three main decant zones were observed as shown in Figure 6-10. It should be noted that the decant zones towards the north-west Main Reef outcrop, and the north-western zone (where the decant surfaces along an open pit currently situated at approximately 100 mbgl), could only be observed when the tracer plume concentration was cut-off at 10 mg/L. When the tracer plume concentration of 100 mg/L is referenced, the only decant point was to the south-east of the ERB plant situated on the Blesbokspruit River footprint between Sub Nigel #1 and Maryvale #5 shafts.

The simulated concentrations for Scenario 2 are shown below in Figure 6-7. The Grootvlei #3 shaft concentration was measured at the same depth disposal is taking place. Given this observation depth, tracer plume concentrations were first detected in 2017 (2 years after deposition started), with the 100 mg/L threshold reached in 2025. The maximum concentration reached in the shaft was simulated at 462 mg/L. After 44 years of pumping (2059) the tracer mass was detected at surface in Grootvlei #3 shaft with concentrations peaking at 4.59 mg/L. The tracer plume reached the green sill boundary around the same time the peak concentrations were detected in Grootvlei #3 shaft, and the mass accumulated at the green sill (aquitard) interface until reaching a peak concentration of 66 mg/L (2021).

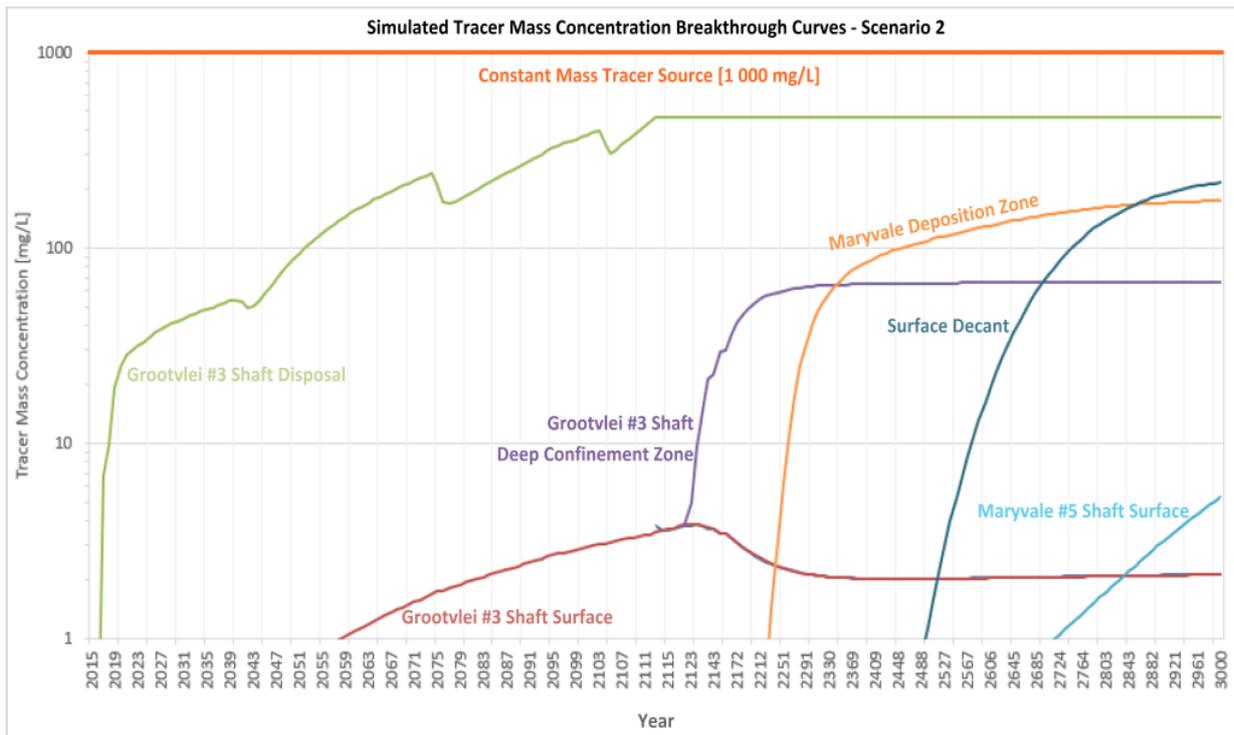


Figure 6-7: Simulated Tracer Mass Concentratio Breakthrough Curves for Scenario 2

The Maryvale #5 receptor was reached 217 years after sludge deposition started and the highest concentration simulated in the model was calculated at 170 mg/L. The tracer plume was detected at surface in the shaft approximately 700 years following deposition. No concentrations were computed to reach the Sub-Nigel #1 shaft in any of the observed locations with depth (i.e. deposition zone, green sill aquitard, or surface).

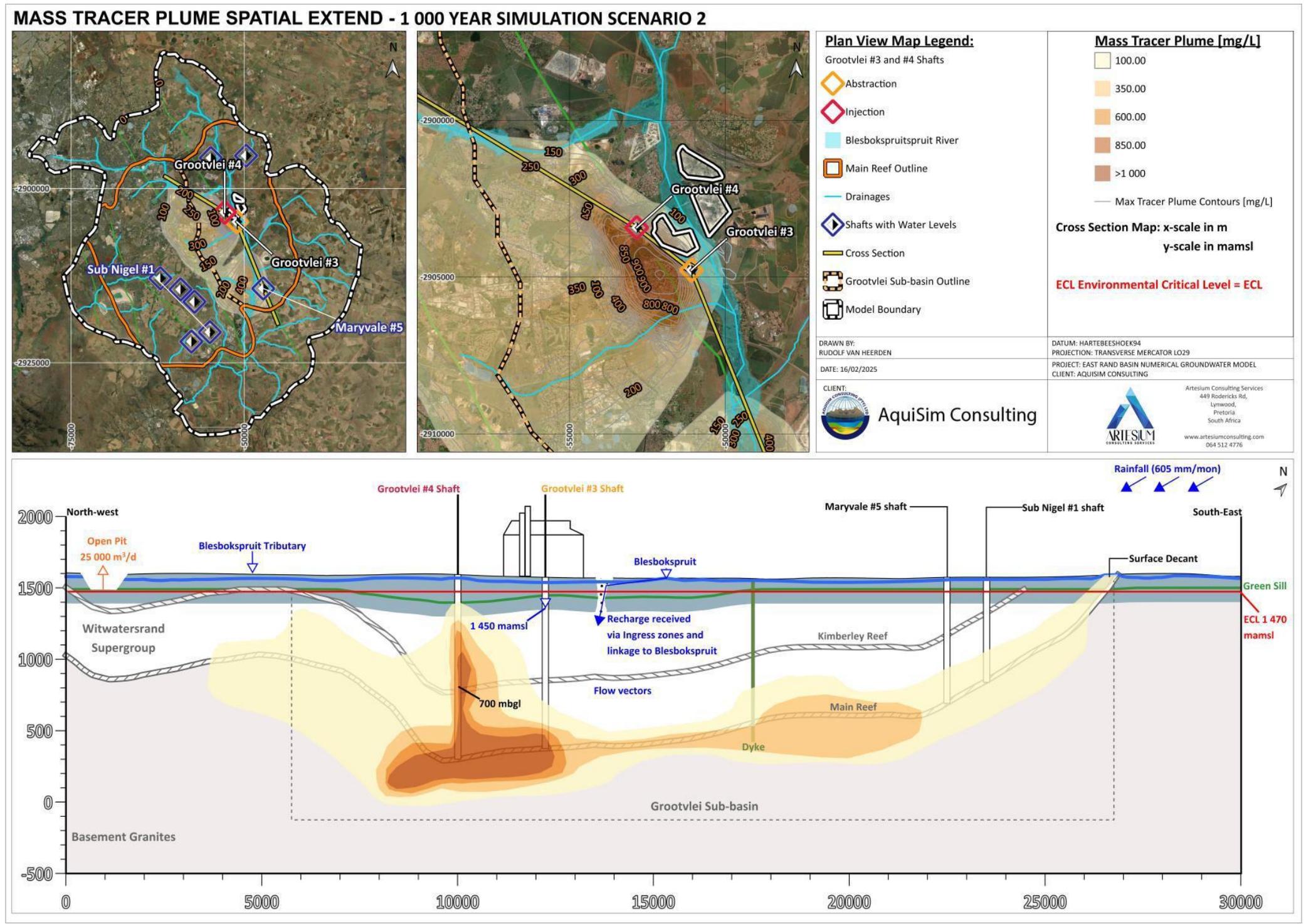


Figure 6-8: Transient Mass Tracer Simulated Plume Results – 1 000 Years Post Deposition for Scenario 2

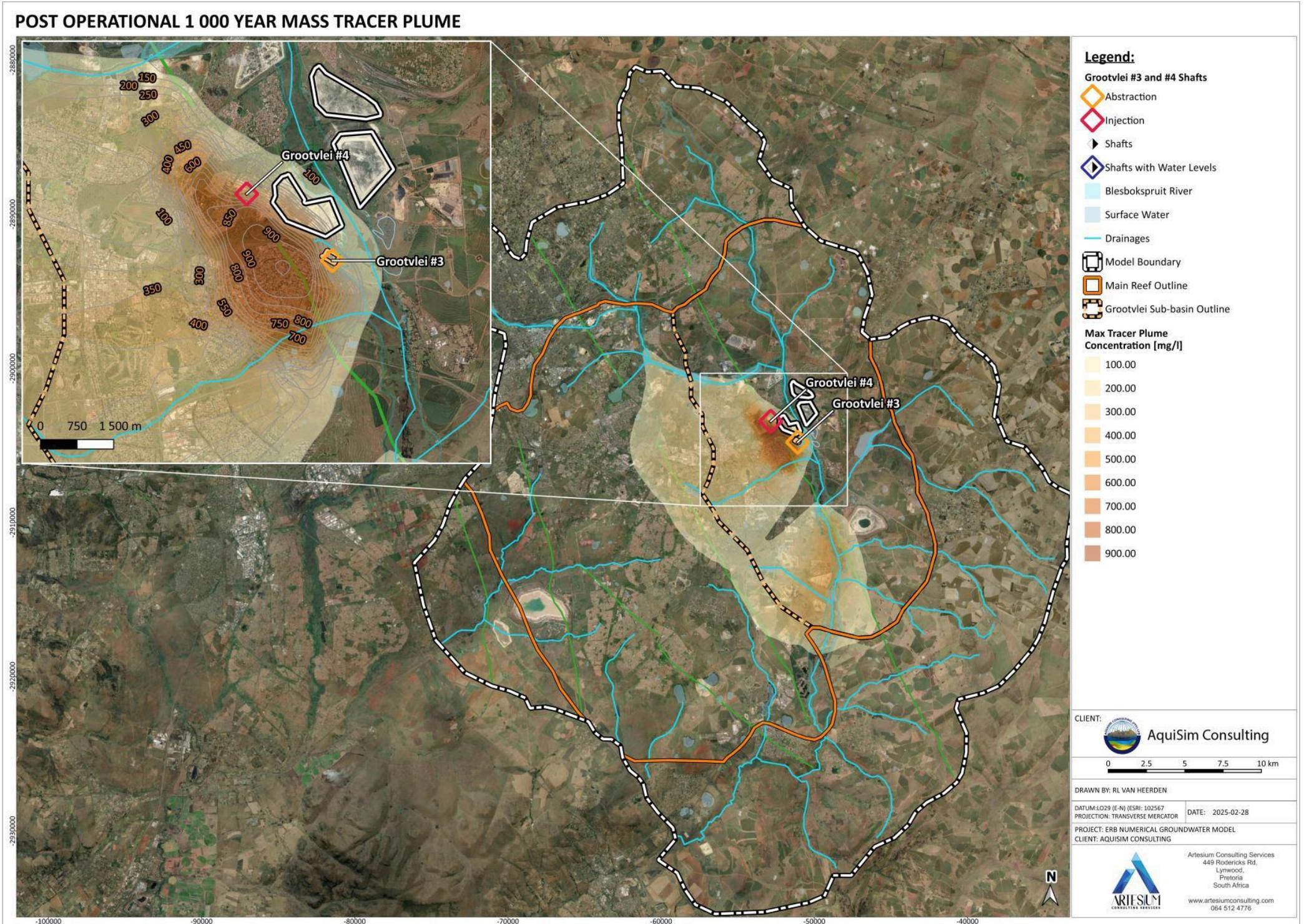


Figure 6-9: Transient Mass Tracer Simulated Plume Results – 1 000 Years Post Deposition for Scenario 2 – Zoomed in Spatially

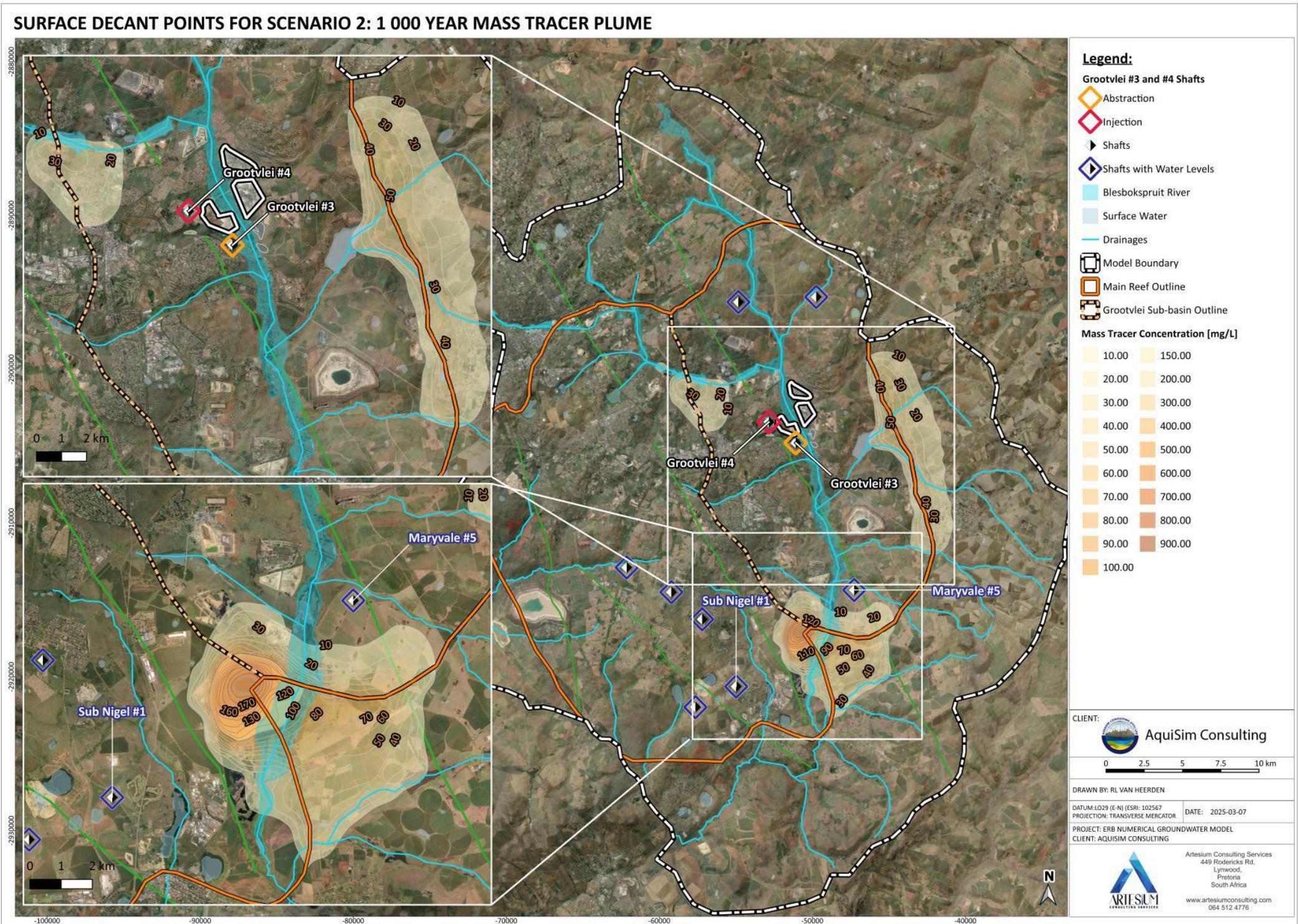


Figure 6-10: Decant Zones from Simulated Tracer Mass Plume – 1 000 Years Post Deposition (Scenario 2)

Table 6-1: Summarised Darcy Flux Calculations

No	Zone	Formation (entity)	Horizontal Hydraulic Conductivity (Kxy)	Vertical Hydraulic Conductivity (Kz)	Horizontal Head Gradient (1)	Vertical Head Gradient (1)	Kinematic Porosity (1)	Horizontal Source-Pathway Distance (m)	Vertical Source-Pathway Distance (m)	Horizontal Source Flow Prdlr 2 Tube Surface Area 1 (Disposal Zone) (m2)	Vertical Source Flow Prdlr 2 Tube Surface Area 2 (Confinement Zone) (m2)	Horizontal Darcy Flux qxy (m/d)	Vertical Darcy Flux qz (m/d)	Plume Horizontal Flow Rate (m3/d)	Plume Vertical Flow Rate (m3/d)	Flow Vector ratio (qz/qv)	Water volume in storage (mil m3)
1	Disposal Zone	Main Reef Grootvlei Sub-Basin	100	100	2.65E-04	2.65E-08	0.7	3 774	1 225	3 202	12 428 246	2.65E-02	2.65E-06	84.791	32.9	1.00E-04	1.82E+08
2	Confinement Zone (deep)	Wits Quartzite	3.54E-01	3.54E-01	2.65E-04	3.21E-07	0.01	3 774	1 125	3 202	12 428 246	9.37E-05	1.14E-07	0.300	1.414	1.21E-03	1.36E+09
3	Confinement Zone (shallow)	Green Sill Aquitard	5.00E-06	5.00E-08	2.65E-04	8.60E-03	0.01	3 774	1 390	3 202	12 428 246	1.33E-09	4.30E-10	4.25E-06	0.005	3.24E-01	3.64E+07
4	Receptor 1	Grootvlei #3 Shaft Pumping Discrete Shaft	100	100	4.24E-04	4.31E-02	0.7	2 218	365		28	4.24E-02	4.31E+00	0.000	122	1.02E+02	-
5	Receptor 2.a	Sub-Nigel #1 Shaft Surface Decanting	2.6	5.18E-04	5.75E-05	4.12E-04	0.7	17 329	713		28	1.49E-04	2.13E-07	0.000	6.03E-06	1.43E-03	-
6	Receptor 2.b	Sub-Nigel #1 Shaft Sub-Surface Decanting	0.9	7.78E-04	5.75E-05	4.11E-04	0.7	17 329	708	3 202	28	5.17E-05	3.20E-07	0.166	9.05E-06	6.19E-03	-
7	Receptor 3a	Merryvale #5 Shaft Surface Decanting	0.7	0.2	8.12E-05	5.47E-04	0.7	12 267	687		28	5.68E-05	1.09E-04	0.000	3.09E-03	1.92E+00	-
8	Receptor 3b	Merryvale #5 Shaft Sub-Surface Decanting	0.9	7.78E-04	8.12E-05	5.47E-04	0.7	12 267	682	3 202	28	7.31E-05	4.26E-07	0.234	1.20E-05	5.82E-03	-

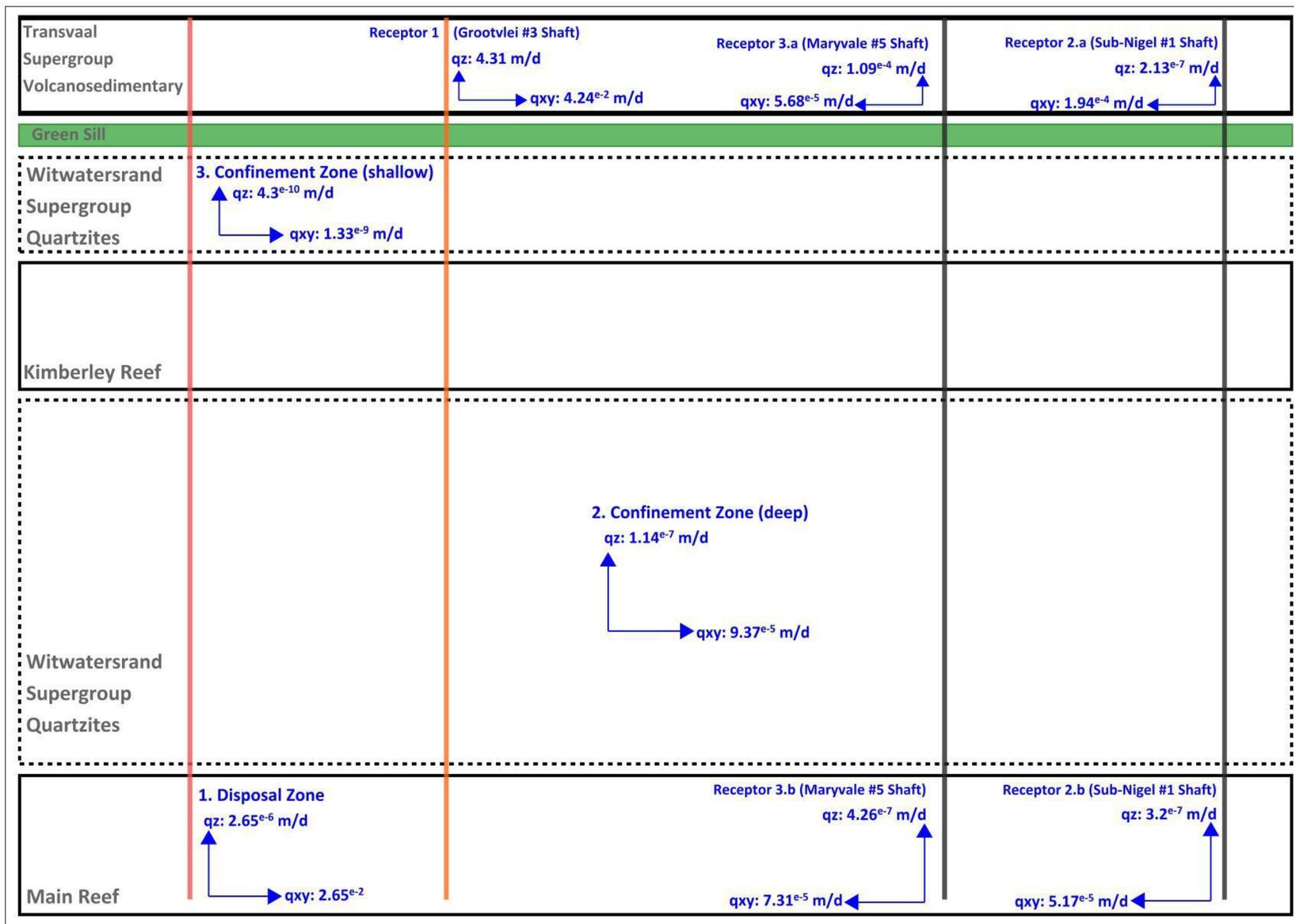


Figure 6-11: Calculated Darcy shown on Modelled Hydrogeological Zones

Table 6-2: Simulated Mass Tracer Concentrat

Observation Point ID	Tracer Source Conc.	Time (y)	Surface (Decant)			Disposal Zone (Main Reef)			Confinement Zone (Shallow)		
			Distance from disposal zone centre (m)	Tracer Peak Concentration at Obs Point (mg/L)	Ratio Peak Conc: Source	Distance from disposal zone centre (m)	Tracer Peak Concentration at Obs Point (mg/L)	Ratio Peak Conc: Source	Distance from source center (m)	Tracer Peak Conc (mg/L)	Ratio Peak Conc: Source
Grootvlei #3 Shaft_Surface	1000	10	1 409	0	0.00E+00	2 350	34	3.40E-02	1 095	0	0.00E+00
Grootvlei #3 Shaft_Surface	1000	100	1 409	3	3.46E-03	2 350	462	4.62E-01	1 095	251	2.51E-01
Grootvlei #3 Shaft_Surface	1000	1000	1 409	2	2.12E-03	2 350	462	4.62E-01	1 095	251	2.51E-01
Nigel #1 Shaft	1000	10	17 329	0	0.00E+00	13 631	0	0.00E+00	13 631	0	0.00E+00
Nigel #1 Shaft	1000	100	17 329	0	0.00E+00	13 631	0	0.00E+00	13 631	0	0.00E+00
Nigel #1 Shaft	1000	1000	17 329	0	0.00E+00	13 631	0	0.00E+00	13 631	0	0.00E+00
Merryvale #5 Shaft	1000	10	12 267	0	0.00E+00	12 267	0	0.00E+00	12 267	1.99	1.99E-03
Merryvale #5 Shaft	1000	100	12 267	0	0.00E+00	12 267	0	0.00E+00	12 267	1	1.46E-03
Merryvale #5 Shaft	1000	1000	12 267	0	0.00E+00	12 267	173	1.73E-01	12 267	0	0.00E+00

6.4 Darcy Flux Calculations

The darcy flux calculation results are shown in Figure 6-11 with the data used for the calculations summarised Table 6-1. Scenario 2 was used to conduct the calculations as this was the most conservative estimate for the mass tracer plume. The horizontal and vertical darcy flux for the disposal zone was calculated at 2.65×10^{-2} and 2.65×10^{-6} m/d, respectively, compared to the deep confinement zone (Witwatersrand Supergroup) that had computed darcy flux values of 9.37×10^{-5} and 1.14×10^{-7} m/d.

The darcy flux calculated in confinement zone is considered low, because of the depth (>1 km) of the Grootvlei sub-basin the flow velocity of the groundwater when observed from surface is considered almost stagnant. The only mechanism increasing the flow velocities within the sub-basin is the pumping from Grootvlei #3 shaft and even when this shaft is simulated to be pumped for 1 000 years, no significant mass was transported to the surface.

7 CONCLUSIONS

From the findings of the model update the following conclusions were made:

1. The current volume of solid sludge deposited is $75\,944\text{ m}^3$ (106 3221.6 tons) assuming a density of $1\,400\text{ kg/m}^3$, with the main reef void volume calculated at 181 mil m^3 . If referred to the Grootvlei sub-basin spillway as the highest point to where sludge can be deposited ($\pm 580\text{ mamsl}$), the reef is currently filled up to 0.2% capacity. The source therefore would have the approximate proportions of $8 \times 2\,240 \times 5\,666\text{ m}$ (Height x Width x Length).
2. If current deposition rates are sequenced for a 100 years, the Grootvlei sub-basin will be filled up to approximately 17% capacity. Noted, that this is not even considering the volume of the Kimberley Reef and associated mined out voids, and the voids from tunnels and associated mine infrastructure voids are also not considered in this calculation. This is just assuming the main reef with a 1 m thickness with 70% void space.
3. The water quality of the injected sludge water was not known, and was estimated at approximately $1\,500\text{ mg/L}$ compared to Central Rand Basin water Qualities, given $2\,672\text{ mg/L}$ (CRB sludge) divided by $3\,712\text{ mg/L}$ (CRB effluent) times the average ERB effluent ($2\,100\text{ mg/L}$), ERB TDS sludge mass load equals $1\,500\text{ mg/L}$. A mass tracer plume $1\,1000\text{ mg/L}$ was therefore considered as currently the sludge deposited into the #4 shaft had TDS concentrations that are lower than the in-situ AMD water in the Basin.
4. The simulations revealed that should pumping from Grootvlei #3 continue, the sludge mass plume would remain relatively stable or stagnant with a footprint of $1\,000\text{ ha}$ at 335 mamsl .
5. The most conservative estimate for a mass tracer plume given 100 years of sludge deposition, after which the pumping from Grootvlei #3 shaft was ceased, had a maximum plume extend of $23 \times 10\text{ km}$ when observed in the disposal zone (at 1.4 km depth), and decants at 3 main zones at surface along

the main reef basin outcrops.

6. The horizontal and vertical darcy flux for the disposal zone was calculated at $2.65e^{-2}$ and $2.65e^{-6}$ m/d, respectively, compared to the deep confinement zone (Witwatersrand Supergroup) that had computed darcy flux values of $9.37e^{-5}$ and $1.14e^{-7}$ m/d.
7. Uranium was below detection (0.015 mg/L) in most samples taken from the shaft (July 2017 to March 2019) and was only detected in five AMD abstraction samples (April 2019 to May 2020) which averaged 0.043 mg/L. The November 2024 concentrations in AMD water and effluent water (0.021 mg/L) matched exactly, which indicates minimal U is disposed of via the sludge as it is not captured by plant processes. Currently, uranium analysis of the sludge is being undertaken, and the results will be analysed by AquSim to quantify the U concentrations associated with disposal.
8. The main pathway for the tracer source to reach possible surface receptors such as groundwater users, surface water features (dam, rivers wetlands), is the shafts, main reef and Kimberley Reef voids, other shallow mined out areas, and the open pit located to the north-west of the ERB plant and this would only occur if all pumping from Grootvlei #3 shaft is stopped and the water levels within the basin recovers completely.

8 RECOMMENDATIONS

The following is recommended from the findings of the investigation:

1. It is recommended that the plant process SOP's be upgraded to remove uranium from the abstracted AMD water before it is disposed into the Blesbokspruit. This would ensure that the U gets captured within the sludge and is disposed of in the Grootvlei sub-basin. Currently, it appears that the bulk of the U mass possible abstracted from the AMD water is being discharged into the Blesbokspruit River and would eventually accumulate in the reed beds along the drainage system.
2. Even though the disposal within the Grootvlei sub-basin is considered a viable long-term (□ 100 years) solution for disposal of sludge, deposition into the alternative sub-basins should be considered. The sub-basins underlying the Sallies and Vlakfontein Deep shafts are deeper when compared to the Grootvlei sub-basin. This would increase the long-term viability of deposition if practically feasible.
3. It is recommended that the geochemistry of the sludge sampled and analysed, and the radiological risks (conducted by AquSim) be characterised.
4. It is recommended that a density dependent flow numerical model be conducted.
5. The liquid fraction of the deposited sludge be analysed on a quarterly basis to determine if the water quality of said sample fluctuates, if not then the sludge water sample can be sampled on an annual basis and be incorporated into the monitoring protocol.

9 REFERENCES

1. AGES. (2006). Regional groundwater flow management model for the Far East Rand Basin. (AGES Technical Report no.: AS/R/06/02/10, dated February 2006).
2. ASA. (2022). Nafasi ERB AMD Water Level Rise Investigation – Risk Assessment. (Artesium SA Technical Report no.: 2022-067, dated 8 November 2022).
3. Barnard H.C., and Baran E. (1999). 1:500 000 Hydrogeological Map Series of the Republic of South Africa: 2526, Johannesburg.
4. Barnard, H.C. (2000). An explanation of the 1:500 000 hydrogeological map: Johannesburg 2526. Department of Water Affairs and Forestry.
5. Chief Directorate: National Geo-spatial Information (CD: NGI). (2024). 1:50 000 Topographical Map Series: 2628DA, 2628CB, 2628BC. Department of Agriculture, Land Reform and Rural Development, South Africa.
6. Council of Geoscience. (2007), 1:50 000 Geological Map Series 2628AD (Springs).
7. Council of Geoscience. (2007), 1:50 000 Geological Map Series 2628AB (Benoni).
8. Council of Geoscience. (2007), 1:50 000 Geological Map Series 2628AD (Endicott).
9. Council of Geoscience. (2008), 1:50 000 Geological Map Series 2628BA (Delmas).
10. Department of Environmental Affairs. (2018) National Environmental Management Act (NEMA), 1998 (Act no. 107 of 1998). National guideline on minimum information requirements for preparing environmental impact assessments for mining activities that require environmental authorisation.
11. Department of Water and Sanitation (DWS) (2013). Groundwater Resource Directed Measures (GRDM). Version 2.3.2.
12. Department of Water and Sanitation. (2016). New nine (9) water management areas of South Africa. Government Gazette No. 40279, 16 September 2016. Pretoria: Government Printer.
13. Department of Water and Sanitation. (2022). Website link: <https://www.dws.gov.za/Hydrology/Default.aspx>
14. Esri. (2025). Esri,n.d. Esri Imagery. Available at: https://server.arcgisonline.com/arcgis/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}. [Accessed 14 February 2025].
15. Exigo. (2017). East Rand Basin Flooding and Sludge Disposal: Flow and Mass Balance Modelling. (Exigo Groundwater specialist report Draft no.: ES15/205 V2, dated 10August 2017).
16. Feflow Finite Element Groundwater flow model – www.feflow.info.
17. Foster, M.B.J. (1988). Geological control of aquifer properties of the Chuniespoort Group in the Klip River

Valley and Natalspruit Basin, Transvaal (Master's thesis, Rhodes University, Grahamstown).

18. Lubbe, C. Bosch, P.J.A. Marais, A.W.C. and Du Doit, M.C. (2007). The Geology of the Benoni Area. Geological Explanation Sheet 2628AB Benoni Scale 1:50 000. Council for Geoscience South Africa.
19. MacConachie, H. (1959). Shaft sinking practice in South Africa. Journal of the Southern African Institute of Mining and Metallurgy, 59(11), pp.569-595.
20. Opperman, R. & P.J.A. Marais. (2005). The Geology of the Springs and Endicott Areas. Geological Explanation Sheet 2628AD and 2628BC Scale 1:50 000. Council for Geoscience South Africa.
21. Parsons R. (1991) A South African Aquifer System Management Classification. Water Research Commission. WRC Report no KV 77/95.
22. Scott, R. (1995). Flooding of Central and East Rand Gold Mines: An Investigation Into Controls Over the Inflow Rate, Water Quality and the Predicted Impacts of Flooded Mines: Report. WRC.

10 APPENDIX A: NUMERICAL MODELLING ASSUMPTIONS, MATERIAL PROPERTIES AND CALIBRATION

10.1 Steady State Numerical Model Calibration

The Steady State model (SS Model) was calibrated under current (2017) conditions. The average water levels in 2017 for both the shaft and monitoring boreholes were considered stable for that year, and the average for the year was used for steady state flow calibration. The steady state calibration focused spatially on the injection and abstraction sites and the correlation between the simulated and measured hydraulic heads are summarised in Table 10-1. The model surrounding the injection/abstraction zone was considered calibrated, with a calculated RMSE of 0.7% and a correlation factor of 99%.

The simulated hydraulic heads in the regional shafts (>10 km from Grootvlei #3 and #4 shafts) was higher than measured values, which would be considered conservative when simulating possible decant locations. The presence of plugs, collapsed sidewalls, silted up shafts, plugs, and numerous side-tunnel connections made the calibration of steady state heads at these locations difficult. A more complex geometry with regards to the old mining infrastructure (shafts and tunnels) would have to be incorporated into the model should this calibration need be considered.

Table 10-1: Steady State Model Calibration Summary

Site name	Date	Measured Head (mamsl)	Simulated Head (mamsl)	Residual Error Above or below actual (m) - RE	Absolute Error (m) - AE	Root Square Error (m) - RSE
EBH-01	Average of 2017	1 571	1 575	-5	5	21
EBH-02	Average of 2017	1 572	1 574	-2	2	3
EBH-03	Average of 2017	1 572	1 570	2	2	3
EBH-04	Average of 2017	1 566	1 571	-4	4	17
Grootvlei #3 shaft	Average of 2017	1 449	1 447	2	2	2
Average		1 546	1 547	-1	3	9
Minimum		1 449	1 447	-5	1.58	2.48
Maximum		1 572	1 599	2	136	18 411
Correlation (R)		0.52				
					ME	-1
					MAE	3
					RMSE	0.7%
Minimum Hydraulic Head in Model						1 448
Max Hydraulic Head in Model						1 904

***ME: Mean Error**

****MAE: Mean Absolute Error**

*****RMSE: Root Mean Square Error**

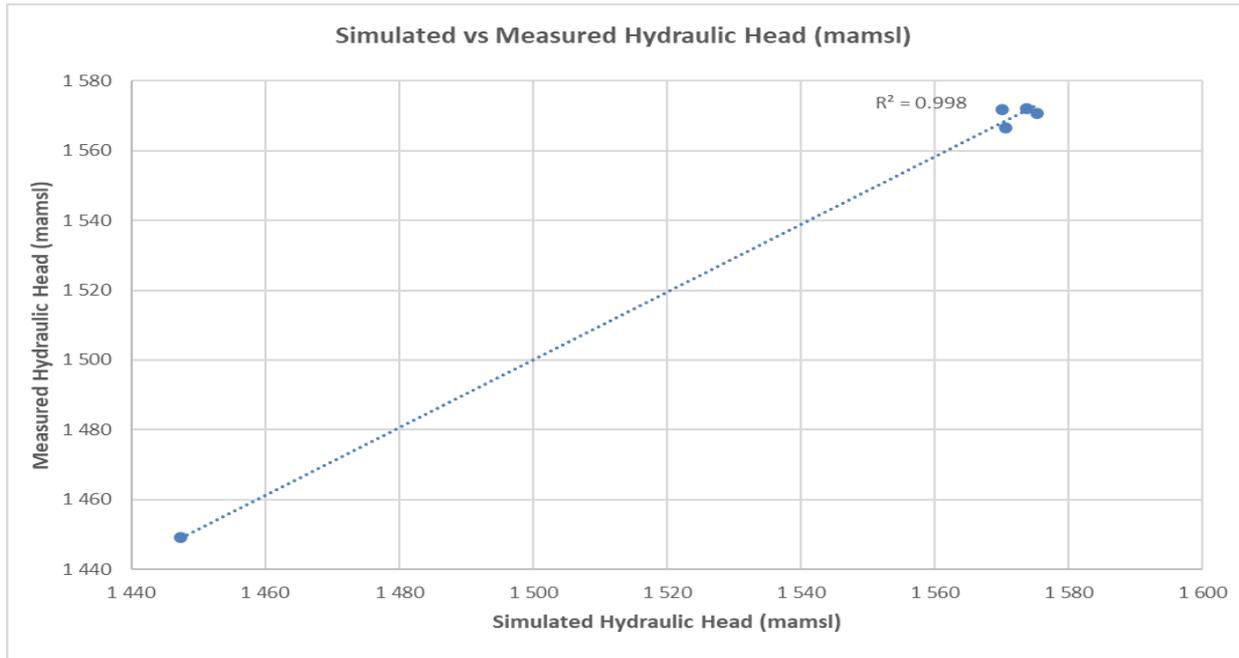


Figure 10-1: Correlation of Simulated vs Observed Hydraulic Heads

10.2 Transient State Model Calibration

The transient state model calibration for Grootvlei #3 shaft is shown in Figure 10-2. The abstraction volumes from the shaft along with transient recharge was simulated. The calibration was considered good, except for the period when pumping stopped post 2022. The simulated hydraulic heads were lower compared to the actual hydraulic heads as the storage in the mine voids and tunnels are high. In reality, after the water levels in Main Reef recovered and the abstraction was continued, the measured water level did not drop in the shaft as simulated in the model. This is because of the amount of water released from storage from the voids of old mine workings (unknown volume). The abstraction would have to dewater these voids over time in order to drop the hydraulic heads in the Main Reef.

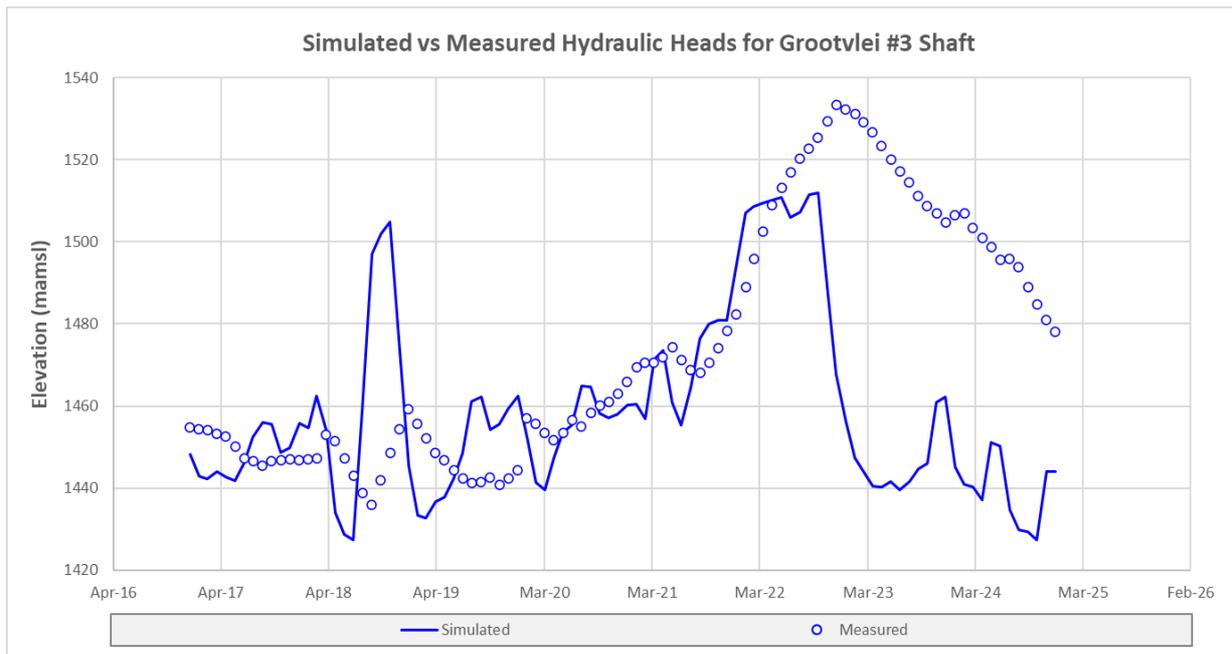


Figure 10-2: Transient State Model Simulated vs Measured Hydraulic Heads for Grootvlei #3 Shaft

10.3 Assumptions and Limitations

The following assumptions were made with listed limitations:

- It was assumed that the Blesbokspruit recharges the semi-confined ERB aquifer via ingress zones. 85% of the water pumped from the Grootvlei #3 shaft is recharge via the Blesbokspruit and does not originate from the dolomite aquifer.
- The system was considered in Steady State in 2017 following a prolonged period of abstraction, the hydraulic heads in the basin was considered stable.
- The accuracy and scale of the assessment will result in acceptable deviations at specific points e.g., individual boreholes and shafts.
- Dykes and faults inferred to be ± 20 m thick, with a contact zones acting as a preferential pathway represented in the model with a discrete feature (0.1 m thick).
- The Kimberley reef bathymetry was not known, and it was assumed that the Kimberley reef is situated 500 m above the Main Reef and would have the same shape (geometry) as the Main Reef.
- It was assumed that both the Main Reef and Kimberley Reef would have a thickness of 1 m, and that they are completely mined out.
- Mine out areas was assumed to be 70% voids
- Shaft depths were unknown, and it was assumed that the shafts were constructed to access Main

Reef, and thus their depths were equal to the depth of Main Reef for each shaft location.

- The integrity of the sidewalls of the shafts were not known, and it was assumed that they would be weathered in a degree.
- No external abstraction from surrounding boreholes were considered.
- The water quality of the regional basin was not known, and it was assumed that the water quality (AMD) water at the Grootvlei #3 and #4 shafts would represent the whole basin.

When assumptions were made or reference values used, a conservative approach was followed aligned with the precautionary principle (NEMA, 1998). A groundwater model is a representation of the real system. It is therefore an approximation, and the level of accuracy depends on the quality of the data that is available. The purpose of the model was not to simulate the actual field conditions (i.e., every dyke and fracture), but to simulate the proposed abstraction from the on-site boreholes and investigate the possible impacts on the surrounding environment. The model input parameters are presented in Table 10-2.

Table 10-2: Model Input Parameter Uncertainty

Input parameter	Source, parameter, or assumption description	Data uncertainty
Topography (DEM)	1:50 000 topographical map series of South Africa was used for the elevation data.	Low
Rivers, streams, drainages	Digitised from topographical maps and aerial imagery (1:50 000 scale), as well as generated from the model DEM, to ensure drainages are placed at appropriate low-lying places in the model topography. Particular care was placed in digitizing the Blesbokspruit with its wide (>500 m) floodplain, and incorporating it into the model.	Low
Lithology	Council for Geoscience 1:50 000 Geological Map Series) 2628AB, 2628AD, 2628BA, and 2628BC Rand.	Moderate
Weathered Zone Thickness	An average depth was used derived from the Murray & Roberts Geological Plan and Profile across the tunnel alignment.	Moderate
Geological structures	Various geological structures were present on the Aerial Magnetic Map, however, there appears to be a gap in the surveyed data, and it was not clear whether this dyke/structure extended past the injection/abstraction site.	High
Ingress Zones	Ingress zones refer to the zones where surface water provided a constant recharge boundary and a zone that is more permeable (higher hydraulic conductivity) is present and would recharge the semi-confined East Rang Basin. The only inferred recharge zone incorporated into the model, was the sinkholes located to the east of the site. In reality multiple ingress zones would be present in the form of old mine workings voids and tunnels, that would act as preferential pathways for surface water to recharge the semi-confined aquifer.	High
Neighbouring Boreholes and pumping rates	No abstraction volumes from neighbouring properties in the ERB watershed was available. No pumping was simulated in the model from neighbouring boreholes within the watershed.	High

Input parameter	Source, parameter, or assumption description	Data uncertainty
Abstraction Volumes (Grootvlei #3 shaft)	Abstraction volumes was received from the client in daily flow rates/volumes.	Low
Injection Volumes (Grootvlei #4 shaft)	Injection volumes was received from the client in daily flow meter readings and the volumes were calculated from them.	Low
Mian Reef and Kimberley Reef Bathymetry	The Main Reef shape (X,Y,Z) data was gathered from the project archives and cross-referenced conceptually with geological cross section Lubbe et al., (2007). The Kimberley Reef was assumed to be 500 m above the Main Reef and has the same geometry.	Moderate
Rainfall	Rainfall data is recorded on-site at the ERB plant and was used for all model simulations.	Low
Steady State Modelling Parameters		
Boundary conditions	Rivers and drainages within the model domain are described by fixed head boundary conditions and they can both take water out of the system and recharge the aquifer system along the perennial drainages.	Low - Moderate
Recharge	The recharge across the model domain was calibrated according to the measured monitoring data (groundwater levels) and according to the seasonal variances in the dewatering rates. The bulk of the recharge received is via the surface water systems recharging the semi-confined aquifer.	Moderate
Initial Hydraulic Heads	The water levels in the ERB are dynamic, and are either recovering or being drawn down from pumping. The initial conditions were therefore not considered and the system was considered in steady state during the 2017 year, when hydraulic heads in the boreholes and shafts (shallow and deeper aquifer) were most stable.	Moderate
Hydraulic Conductivity	The hydraulic conductivity from previous model calibration was used as initial values. The hydraulic conductivity of the mining voids and collapsed zones are high, and it was assumed that the	Moderate
Transient State Modelling Parameters		
Monitoring data	Long-term monitoring data (2017 - 2024) was available for transient calibration. In long term modelling scenarios, the steady state flow and transient tracer mass was used to conduct simulations. The transient calibration was used to test the sensitivity of the model parameters used for input.	Low
Specific Storage	The volume of water that a unit volume of aquifer releases from or takes into storage per unit change in head. $S = S_s \times D$. S_s . The storage available in mine voids are not known, and the transient calibration proved that the deep semi-confined aquifer is highly dependent on this parameter.	High
Transient Mass Tracer Parameters		
Porosity (%)	A conservative porosity value of 7.5% was used across the model domain.	High

Table 10-3: Initial Model Parameters

No	Layer	Selection	Hydraulic Zone	Thickness (m)	Transmissivity (m ² /d)	Avg Hydraulic Conductivity K (m/d)	Hydraulic Conductivity Kx (m/d)	Hydraulic Conductivity Ky (m/d)	Hydraulic Conductivity Kz (m/d)	Ss (1/m)	S (1)	Porosity	Ass_R (mm/a)	Recharge (%)	Recharge (m/d)
1	1	Alluvium	Weathered Zone	5	2.667	0.53	7.00E-01	7.00E-01	2.00E-01	2.00E-02	1.00E-01	7.50E-01	25	4.13%	6.85E-05
2	1	Karoo Dolerite	Weathered Zone	5	1.296	0.259	2.59E-01	2.59E-01	2.59E-01	2.00E-02	1.00E-01	7.50E-01	12	2.00%	3.32E-05
3	1	Dykes	Weathered Zone	5	1.295	0.259	2.59E-01	2.59E-01	2.59E-01	2.00E-02	1.00E-01	7.50E-01	12	2.00%	3.32E-05
4	1	Karoo Sandstone	Weathered Zone	5	8.634	1.727	2.59E+00	2.59E+00	5.18E-04	2.00E-02	1.00E-01	7.50E-01	26	4.30%	7.12E-05
5	1	Karoo Dwyka Tillite	Weathered Zone	5	0.663	0.133	1.99E-01	1.99E-01	3.97E-05	2.00E-02	1.00E-01	7.50E-01	12	2.00%	3.32E-05
6	1	Malmani Dolomite	Weathered Zone	5	26.668	5.334	8.00E+00	8.00E+00	8.64E-04	2.00E-02	1.00E-01	7.50E-01	42	7.00%	1.16E-04
7	1	Black Reef Quartzite	Weathered Zone	5	5.767	1.153	1.73E+00	1.73E+00	3.46E-04	2.00E-02	1.00E-01	7.50E-01	12	2.00%	3.32E-05
8	1	Alberton and other Lava	Weathered Zone	5	0.333	0.067	1.00E-01	1.00E-01	2.00E-05	2.00E-02	1.00E-01	7.50E-01	12	2.00%	3.32E-05
9	1	HalfwayH Granites	Weathered Zone	5	0.333	0.067	1.00E-01	1.00E-01	2.00E-05	2.00E-02	1.00E-01	7.50E-01	18	2.98%	4.93E-05
10	1	Main Reef Outcrop	Weathered Zone	5	155.000	31	3.10E+01	3.10E+01	3.10E+01	2.00E-02	1.00E-01	7.50E-01	18	3.00%	4.97E-05
11	1	Dam River Sediments	Dam/lake sediments	5	2.333	0.467	7.00E-01	7.00E-01	5.18E-05	2.00E-02	1.00E-01	7.50E-01	25	4.13%	6.85E-05
12	1	Ingress Areas	Induced Recharge	5	25.000	5.000	5.00E+00	5.00E+00	5.00E+00	2.00E-02	1.00E-01	7.50E-01	50	8.26%	1.37E-04
13	1	TSF	Induced Recharge	5	0.200	0.040	1.00E-02	1.00E-02	1.00E-01	2.00E-02	1.00E-01	7.50E-01	65	10.74%	1.78E-04
14	2	Karoo Dolerite	Solid and Fractured	109	5.663	0.0519	7.78E-02	7.78E-02	7.78E-05	5.00E-03	5.46E-01	7.50E-01			
15	2	Dykes	Aquitard	109	5.663	0.0519	7.78E-02	7.78E-02	7.78E-05	5.00E-03	5.46E-01	7.50E-01			
16	2	Karoo Sandstone	Solid and Fractured	109	65.506	0.6003	9.00E-01	9.00E-01	7.78E-04	5.00E-03	5.46E-01	7.50E-01			
17	2	Karoo Dwyka Tillite	Solid and Fractured	109	4.338	0.0398	5.96E-02	5.96E-02	5.96E-05	5.00E-03	5.46E-01	7.50E-01			
18	2	Malmani Dolomite	Solid and Fractured	109	0.364	0.0033	5.00E-03	5.00E-03	5.00E-06	5.00E-03	5.46E-01	7.50E-01			
19	2	Black Reef Quartzite	Solid and Fractured	109	37.734	0.3458	5.18E-01	5.18E-01	5.18E-04	5.00E-03	5.46E-01	7.50E-01			
20	2	Alberton and other Lava	Solid and Fractured	109	37.688	0.3454	5.18E-01	5.18E-01	5.18E-05	5.00E-03	5.46E-01	7.50E-01			
21	2	HalfwayH Granites	Solid and Fractured	109	2.191	0.0201	3.01E-02	3.01E-02	3.01E-05	5.00E-03	5.46E-01	7.50E-01			
22	2	Main Reef Pathway	Solid and Fractured	109	54.592	0.5003	7.50E-01	7.50E-01	7.50E-04	5.00E-03	5.46E-01	7.50E-01			
23	2	Open Diggings	Solid and Fractured	109	18.197	0.1668	2.50E-01	2.50E-01	2.50E-04	5.00E-03	5.46E-01	7.50E-01			
24	2	Ingress Areas	Solid and Fractured	109	177.518	1.6267	4.40E-01	4.40E-01	4.00E+00	5.00E-03	5.46E-01	7.50E-01			
25	3 - 4	Karoo Dolerite	Aquitard	20	0.035	0.0017	2.59E-03	2.59E-03	2.59E-08	5.00E-07	1.00E-05	7.50E-01			
26	3 - 4	Dykes	Aquitard	20	0.035	0.0017	2.59E-03	2.59E-03	2.59E-08	5.00E-07	1.00E-05	7.50E-01			
27	3 - 4	Karoo Sandstone	Aquitard	20	0.035	0.0017	2.59E-03	2.59E-03	2.59E-08	5.00E-07	1.00E-05	7.50E-01			
28	3 - 4	Karoo Dwyka Tillite	Aquitard	20	0.001	0.0001	1.00E-04	1.00E-04	1.00E-09	5.00E-07	1.00E-05	7.50E-01			
29	3 - 4	Malmani Dolomite	Aquitard	20	0.058	0.0029	4.32E-03	4.32E-03	4.62E-08	5.00E-07	1.00E-05	7.50E-01			
30	3 - 4	Black Reef Quartzite	Aquitard	20	0.035	0.0017	2.59E-03	2.59E-03	2.59E-08	5.00E-07	1.00E-05	7.50E-01			
31	3 - 4	Alberton and other Lava	Aquitard	20	0.035	0.0017	2.59E-03	2.59E-03	2.59E-08	5.00E-07	1.00E-05	7.50E-01			

ERB Numerical Advective Tracer Transport Model

No	Layer	Selection	Hydraulic Zone	Thickness (m)	Transmissivity (m ² /d)	Avg Hydraulic Conductivity K (m/d)	Hydraulic Conductivity Kx (m/d)	Hydraulic Conductivity Ky (m/d)	Hydraulic Conductivity Kz (m/d)	Ss (1/m)	S (1)	Porosity	Ass_R (mm/a)	Recharge (%)	Recharge (m/d)
32	3 - 4	HalfwayH Granites	Aquitard	20	0.035	0.0017	2.59E-03	2.59E-03	2.59E-08	5.00E-07	1.00E-05	7.50E-01			
33	3 - 4	Main Reef Pathway	Aquitard	20	34.706	1.7353	2.59E+00	2.59E+00	2.59E-02	5.00E-07	1.00E-05	7.50E-01			
34	3 - 4	Ingress Areas	Aquitard	20	11.000	0.5500	5.50E-01	5.50E-01	5.50E-01	5.00E-07	1.00E-05	7.50E-01			
35	3 - 4	Green Sill	Aquitard	20	0.000	0.0000	5.00E-06	5.00E-06	5.00E-09	5.00E-07	1.00E-05	7.50E-01			
36	3 - 4	Ingress Zone	Aquitard	10	20.000	2.0000	2.00E+00	2.00E+00	2.00E+00	5.00E-07	5.00E-06	7.50E-01			
37	5	Karoo Dolerite	Solid and Fractured	100	6.532	0.0653	9.33E-02	9.33E-02	9.33E-03	1.00E-06	1.00E-04	7.50E-01			
38	5	Dykes	Aquitard	100	6.532	0.065	9.33E-02	9.33E-02	9.33E-03	1.00E-06	1.00E-04	7.50E-01			
39	5	Karoo Sandstone	Solid and Fractured	100	39.777	0.398	5.50E-01	5.50E-01	9.33E-02	1.00E-06	1.00E-04	7.50E-01			
40	5	Karoo Dwyka Tillite	Solid and Fractured	100	50.076	0.501	7.15E-01	7.15E-01	7.15E-02	1.00E-06	1.00E-04	7.50E-01			
41	5	Malmani Dolomite	Solid and Fractured	100	4.200	0.042	6.00E-02	6.00E-02	6.00E-03	1.00E-06	1.00E-04	7.50E-01			
42	5	Black Reef Quartzite	Solid and Fractured	100	43.546	0.435	6.22E-01	6.22E-01	6.22E-02	1.00E-06	1.00E-04	7.50E-01			
43	5	Alberton and other Lava	Solid and Fractured	100	25.257	0.253	3.61E-01	3.61E-01	3.61E-02	1.00E-06	1.00E-04	7.50E-01			
44	5	HalfwayH Granites	Solid and Fractured	100	25.257	0.253	3.61E-01	3.61E-01	3.61E-02	1.00E-06	1.00E-04	7.50E-01			
45	5	Main Reef Pathway	Solid and Fractured	100	69.300	0.693	9.90E-01	9.90E-01	9.90E-02	1.00E-06	1.00E-04	7.50E-01			
46	5	Ingress Areas	Solid and Fractured	100	55.000	0.550	5.50E-01	5.50E-01	5.50E-01	1.00E-06	1.00E-04	7.50E-01			
47	6	Wits SG	Solid and Fractured	506	93.586	0.185	1.86E-01	1.86E-01	1.84E-01	4.57E-05	2.31E-02	7.50E-01			
48	6	PO Wits SG	Solid and Fractured	0.1	85.680	857	8.57E+02	8.57E+02	8.57E+02	4.57E-05	4.57E-06	7.50E-01			
49	6	Dykes	Aquitard	506	0.124	2.46E-04	2.46E-04	2.46E-04	2.46E-04	4.57E-05	2.31E-02	7.50E-01			
50	7	Kimberley Reef	Conduit	1	90.000	90.000	9.00E+01	9.00E+01	9.00E+01	5.00E-01	5.00E-01	7.50E-01			
51	7	PO Wits SG	Solid and Fractured	0.1	102.000	1 020.000	1.02E+03	1.02E+03	1.02E+03	5.00E-01	5.00E-02	7.50E-01			
52	7	Dykes	Aquitard	0.1	0.100	1.000	1.00E+00	1.00E+00	1.00E+00	5.00E-05	5.00E-06	7.50E-01			
53	8	Wits SG	Solid and Fractured	500	91.800	0.184	1.84E-01	1.84E-01	1.84E-01	4.63E-05	2.32E-02	7.50E-01			
54	8	PO Wits SG	Solid and Fractured	0.1	71.400	714.000	7.14E+02	7.14E+02	7.14E+02	4.63E-05	4.63E-06	7.50E-01			
55	8	Dykes	Aquitard	500	0.104	2.07E-04	2.07E-04	2.07E-04	2.07E-04	4.63E-05	2.32E-02	7.50E-01			
56	9	Main Reef	Conduit	1	100.000	100.000	1.00E+02	1.00E+02	1.00E+02	5.00E-01	5.00E-01	7.50E-01			
57	9	PO Wits SG	Solid and Fractured	0.1	80.000	800.000	8.00E+02	8.00E+02	8.00E+02	2.53E-02	2.53E-03	7.50E-01			
58	9	Dykes	Aquitard	0.1	0.100	1.00E+00	1.00E+00	1.00E+00	1.00E+00	2.53E-02	2.53E-03	7.50E-01			
59	10	Basement Granites	Solid and Fractured	1 352	2.514	0.002	1.86E-03	1.86E-03	1.86E-03	3.05E-07	4.12E-04	7.50E-01			
60	10	PO Basement Granites	Solid and Fractured	2 300	2.510	0.001	1.09E-03	1.09E-03	1.09E-03	3.05E-07	7.02E-04	7.50E-01			
61	10	Dykes	Aquitard	1 352	0.010	7.43E-06	7.43E-06	7.43E-06	7.43E-06	3.05E-07	4.12E-04	7.50E-01			